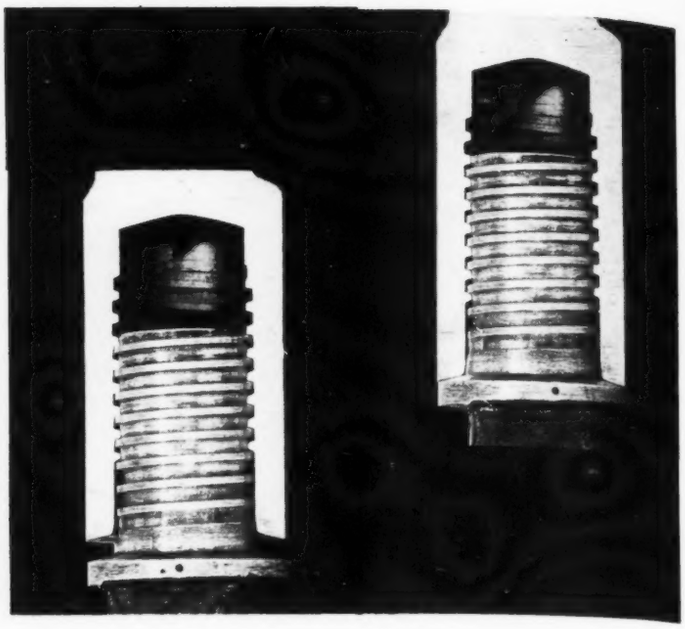
MIDYEAR, 1931



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Petroleum Engineer

The Engineering Magazine of the Oil and Gas Industry

Edited and Circulated Only for those Actively Engaged in the Operating Departments of the Industry

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Volume 2 **MIDYEAR, 1931** **Number 9**

This issue contains

	Page
Increased Speeds Feature Past Year's Drilling Developments By Warren L. Baker	30
Low Pressures May Necessitate Big Air Lift Program for East Texas	34
Equipment Improvements Reduce Lifting Costs at Small Pumping Wells	35
Review of Progress in Production Practice By K. C. Sclater	37
Developments in Pipe Line Construction Progress By J. H. Dameron	40
Progress in Refinery Engineering By F. R. Staley	46
A Novel Pump Station Manifold By R. W. Sparrowhawk	54
Chemical Research and Its Contributions to Refining Progress By Dr. A. E. Dunstan	56
Improved Salvability of Rig Cellar and Foundation Construction Job	62
Progress in Standard Cable Tool Drilling Practice	64
Progress of Slush Pump Pressure Measurements By E. L. Decker	67
A Natural Gasoline Survey of East Texas By F. M. Neely	72
Pressure Control in Modern High-Pressure Absorption Plants By Louis H. Brendel	74
Progress in Study of Pipe Line Corrosion By Stanley Gill	82
Practical Analysis of Lubricating Greases By Dr. Wm. T. Sieber	96
Progress in Accident Prevention in Petroleum Refineries By H. N. Blakeslee	101
Air Filters Prove Beneficial to Pipe Line Station Operation	106
Developments in Refining Pennsylvania Crude Oil By C. M. Ridgeway	109
Pipe Lines Under Construction and Contemplated for 1931	114
Internal Stresses of Wire Lines By Walter Voigtlander	116
The Year's Progress in the California Natural Gasoline Industry By F. L. Kallam	120
Causes, Characteristics and Methods of Treating Oil Field Emulsions By W. F. Cloud	129
Care of Electrical Drilling Equipment By Will C. Barde	134
Applying Creep Stresses to Oil Still Tubes By Roger Stuart Brown	137
Recent Developments in Contact Filtration By George Pfau and C. A. Barrere	140
Shield Welded Pressure Vessels Now Safe for All Hazardous Uses By G. Raymond	147
The Well Method of Producing Oil By W. P. Haseman	152
Recent Progress in Gasoline Treating By Richard H. Cook	162
Transporting Oil Field Materials in South America By Wiley Martin	170
Pipe Line Station Design and Control By John M. McGregor and T. D. Williamson	172

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Our Second Annual Engineering Review

WE OFFER the second Annual Engineering Review Number of The Petroleum Engineer. In it many of the industry's most brilliant technical minds have outlined and interpreted the past year's trends in engineering practices. Replete with graphs, tables, charts and other data their contributions are of incalculable permanent worth. The outstanding impression to be gained from a reading of this material is that during the past year, with its decidedly unsatisfactory economic conditions, there has been no abatement of endeavor on the part of manufacturers of equipment, working in conjunction with company engineers and operating men, in the development of new methods and equipment for the production, refining and transportation of petroleum and its products. On the contrary, lower prices for both raw and finished products have necessitated an even more consistent program of research in the zealous effort of operating men to reduce costs. More open-mindedly than ever before has this research been conducted and a freer exchange of ideas has been apparent.

As a direct result of existing economic stress, production men are tubing wells under pressure as general practice, realizing that, in the long run, their companies will profit by it. We see the introduction of bottom hole chokes for reducing gas-oil ratios, the widespread adoption of slow-speed pumping and the frequent exchange of old equipment for new on small producing wells so that, over a period of years, production might be materially increased and production costs materially reduced.

In the refining branch of the business, a preponderance of engineering thought has been directed toward more general use of control instruments, toward improving furnace design, development of heat-resisting alloys and the perfection of stabilization and vapor recovery equipment.

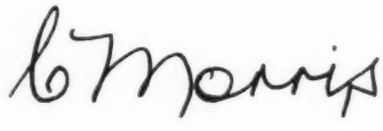
Simultaneously, pipe line engineers have concerned themselves largely with more efficient methods of laying large diameter lines, the further development of automatic and remote-control pump stations and the adaptation of general line equipment to a wider range of use.

Activated always by the needs of the operating fraternity, The Petroleum Engineer early adopted the policy of encouraging its writers to incorporate into their articles at every possible opportunity ideas for the effecting of savings. Often the measure suggested might call for seemingly unwarranted immediate expenditures for replacement of antiquated machinery or outgrown systems, but, in due course, the greater efficiency resulting from the use of modern equipment and improved methods unfailingly justifies their adoption.

Unquestionably, it is this practice of anticipating the problems of its readers and the sincerity of effort on the part of its editorial directors to provide precisely the information needed to cope with these problems that account for the magazine's widespread appeal. An example is the rising interest manifest in the manufacture from natural gas of "dry ice" or solidified carbon dioxide. Realizing also that operating men are looking to it for the latest technical facts, leaders in this phase of the industry are increasingly coming to depend upon The Petroleum Engineer as the foremost medium for exchange of ideas and for giving to their contemporaries the fruits of laboratory research and field tests.

In issuing our second Annual Engineering Review Number we express the belief that each reader will find in it a wealth of usable information and we know that those who have contributed either articles or data have your thanks as well as our own.

As in the case of last year's Review, features such as Month's Highlights in Oildom, Pictorial Petroleum, New Equipment, etc., have been omitted. These will be resumed in our June fifteenth issue.



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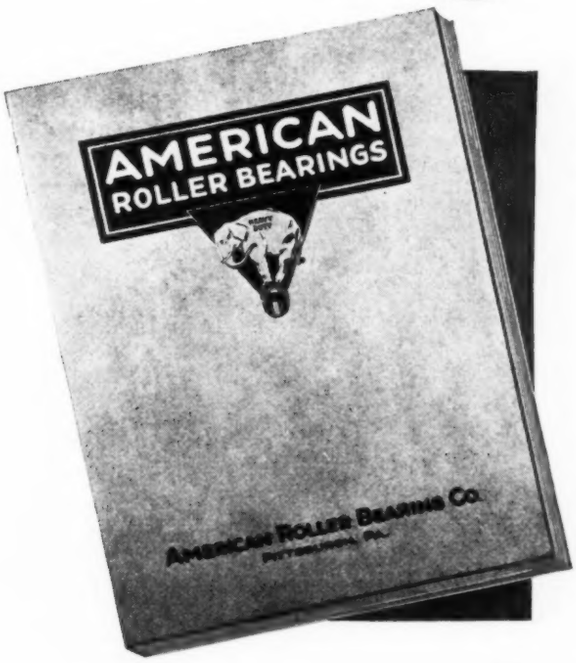

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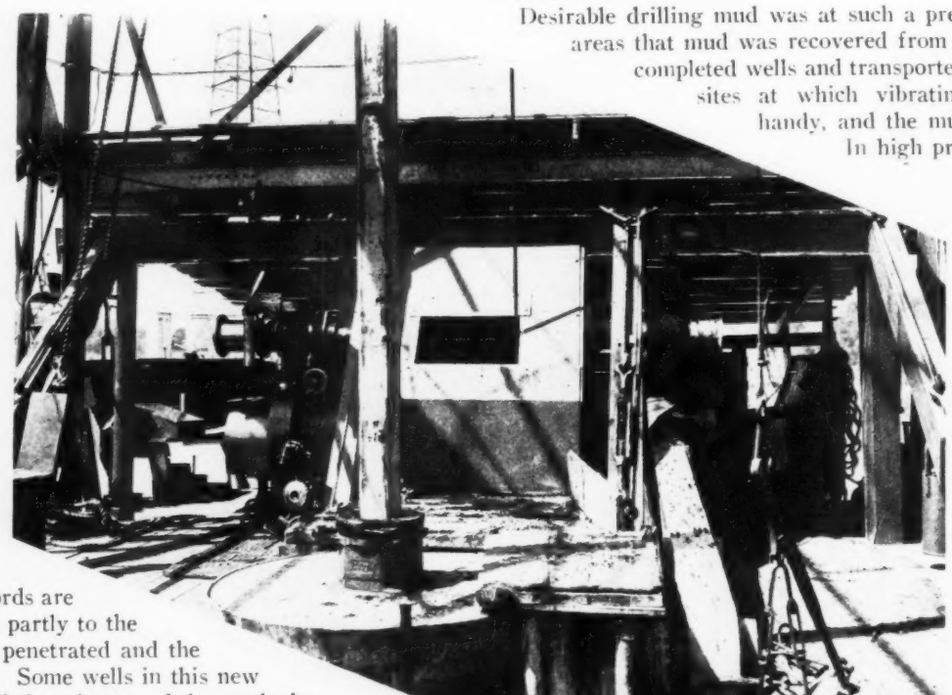
Increased Speeds Feature Past

By WARREN

IN the general adoption of new drilling practices and improved rig equipment during the past year, increased boring speeds were an outstanding accomplishment. New drilling units, capable of generating more power, speed up rig operations, and their sturdier construction and better field care have resulted in fewer shutdowns. Recent improvements indicate that the industry is on the threshold of an engineering development era expected to bring many great advancements in drilling.

Remarkable drilling speeds were made, far exceeding any previous records. Several wells in the 6400-foot Oklahoma City field were completed in 35 to 40 days, including setting two long strings of casing, compared to 80 to 120 days' completion time during the early life of the field. In East Texas remarkable drilling records are being made, due partly to the soft formations penetrated and the shallower depth. Some wells in this new district have drilled to the top of the producing horizon (about 3400 feet) in less than a week after setting surface casing.



Rotary drilling rig floor.

Particular attention has been devoted to drilling muds as a result of activity in high pressure areas, such as Kettleman Hills, Oklahoma City and Hobbs. Greater knowledge of this important phase of rotary drilling has enabled engineers to determine more closely than heretofore the desired mud characteristics best suited to each pool.

It is now general practice to have the drilling mud of sufficient weight to prevent the well blowing out and yet thin enough to carry off the cuttings and permit rapid liberation at the surface of oil gas and cuttings in suspension. Many companies now give strict instructions regarding the thickness and weight of drilling mud to be carried to the drilling contractor. The drilling contractors themselves have found it beneficial to check the condition of the drilling mud regularly. Commercial compounds have been freely used in all the prominent fields of the past year to condition drilling muds.

In the high pressure fields of the Mid-Continent, it is customary to use three large slush ponds at a well. One of these is a settling pit, into which mud returns from the well are led to allow the cuttings to settle out and permit the escape of oil and gas. In California the use of central mud plants for supplying a number of wells with drilling fluids was introduced and their use extended.

The new device for handling drilling muds, the vibrating screen, came into further prominence during the year. These screens are set up at the well discharge trough, the mud passing over them as they are vibrated by a small motor. Foreign particles are rejected and the screened mud sent directly to the suction pits, thus eliminating a settling pit. These screens, obtainable in different meshes, also assist in liberating suspended oil and gas. They have aided in speeding up drilling on wells.

Desirable drilling mud was at such a premium in several areas that mud was recovered from the slush pits of completed wells and transported to new drilling sites at which vibrating screens were handy, and the mud reconditioned.

In high pressure areas, the practice of penetrating the producing horizon with rotary tools was extended. New completion methods, whereby the flow from large, high-pressure producing wells is kept under complete control during the operation of bringing the well in, were notable improvements of 1930. No longer do wells in the Oklahoma City field offer the spectacular and undesirable sight produced by the dangerous practice of cleaning the hole by blowing rotary mud high over the derrick top into the atmosphere and blanketing the adjoining territory with an oily, muddy coat.

The success awarded efforts of oil company and manufacturer's engineers in handling well completions in the Oklahoma City field is attested by the fact that people now motor by these giant wells as they are brought in, unaware that a new well is being added to the pool. There is only a small stream of mud to be seen as it goes into the slush pond with a silence that is more astonishing than the previous roar of a well blowing into the air.

The practice at Oklahoma City is to complete wells through a series of separators, later left in place to handle the flow of oil, gas and sand. Improved, enlarged separators handle the rotary mud as the well cleans itself, discharging it out the bottom to the slush pit. The tremendous duty placed on these separators can be realized when one visions a 6,400-ft. well flowing heavy rotary mud, followed

Year's Drilling Development

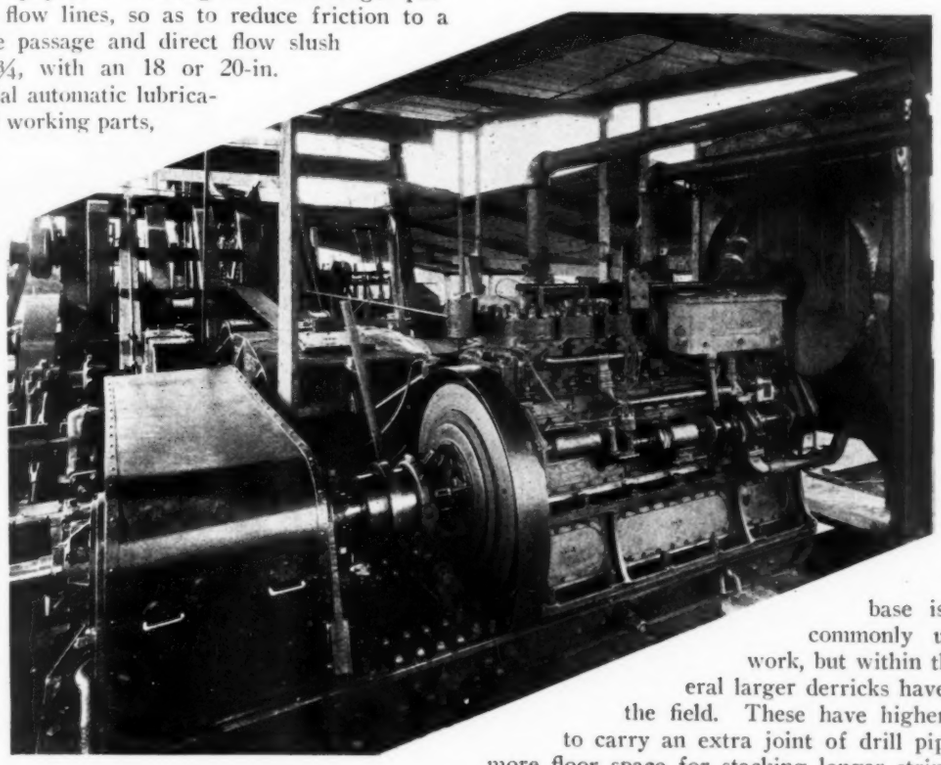
L. BAKER

by a production flow at a daily rate of more than 50,000 barrels of oil and 75,000,000 cubic feet of gas.

There is a growing use of the washing-in completion method. Clear water is pumped down the hole to wash out the rotary mud, discharging it to the slush ponds. When the rotary mud has been discharged, many wells have sufficient pressure to lift the column of clear water from the hole.

Greater depths, with consequent high pressures and the necessity for heavier mud, has brought about several changes in mud-handling equipment. Among these are larger passages and direct flow lines, so as to reduce friction to a minimum. Large passage and direct flow slush pumps, 15 by 7¾, with an 18 or 20-in. stroke, with special automatic lubrication systems to all working parts, are in use today. One manufacturer is marketing a 16-valve, 16 by 8 by 24 pump, with a working pressure of 1,500 pounds.

A rotary drilling hose of greater strength has been developed to withstand the increasing high pressures. Several types of all-steel rotary hose are being marketed.



Gas engine operating drawworks.

Heavily constructed swivels, with four or more heavy duty roller bearings and oil bath, are found on the modernly equipped drilling well. Body thrust bearings are of ample size to absorb the thrust when a load is suddenly released from the bail, and have large fluid passages that reduce the required pressure and increase pumping efficiencies.

Steam generation for power has undergone considerable change and improvement during the year. This progress has resulted in large efficiency increases in power plants mainly through reducing the amount of moisture in the steam; a desired result, as it has reduced steam and boiler water consumption, and increased the capacity, speed and flexibility of the drilling rig.

Oil field boilers equipped with superheating apparatus, are quickly coming into general use, although their introduction for oil drilling purposes was only recent. After the steam is generated in the boiler it is superheated or increased in temperature by flowing it inside a system of tubular units with hot gases outside. Efficient generation and utilization of steam has meant a tremendous saving to drilling contractors and much more satisfactory performance of equipment.

Several auxiliary devices for reducing the steam losses have been designed. Many of these utilize the exhaust steam of the rotary drilling engine for heating the boiler feed water, after which the condensate is rerun to the boilers. Primarily, the results are more steam power with less boiler strain. These steam heaters and condensers have been a very interesting development of the year.

Faster time in running drill pipe has been made possible by the crew being able to stack longer stands of pipe in the taller, larger floor-spaced derricks. With fast hoists and sure-gripping, quick releasing tongs, drilling crews have been able to run long strings of drill pipe in and out of the hole with remarkable rapidity.

The 122-ft. derrick with a 24-ft. by 24-ft. base is still the most commonly used for rotary work, but within the past year several larger derricks have been erected in the field. These have higher fourble towers to carry an extra joint of drill pipe per stand and more floor space for stacking longer strings of pipe.

A number of 136-ft. derricks have been erected in various parts of the country, but these are by no means the tallest. A few 171-ft. derricks have been built, and several 164 feet and 157 feet in height.

Larger cellars than formerly are constructed at most deep drilling wells, especially those in high pressure areas. They are made deep enough so that a man can conveniently work beneath the derrick floor. The practice in many areas is to cement the floor and side walls of the cellars. The larger cellars are necessary to accommodate the larger sizes and greater number of drilling valves now in use.

Fast hoisting is possible through the extra heavy, three-, four-, five- and six-speed type draw works of two and three special heat-treated steel shafts. A new advance in drawworks construction is the molding of the hoisting drum in one piece. In the drawworks of latest design, the hoisting drums are equipped with better brakes of either the water-cooled or air-cooled type.

Many long strings of casing have been run during the year. A world's casing record was established in the North Dome district of Kettleman Hills when the North Ameri-

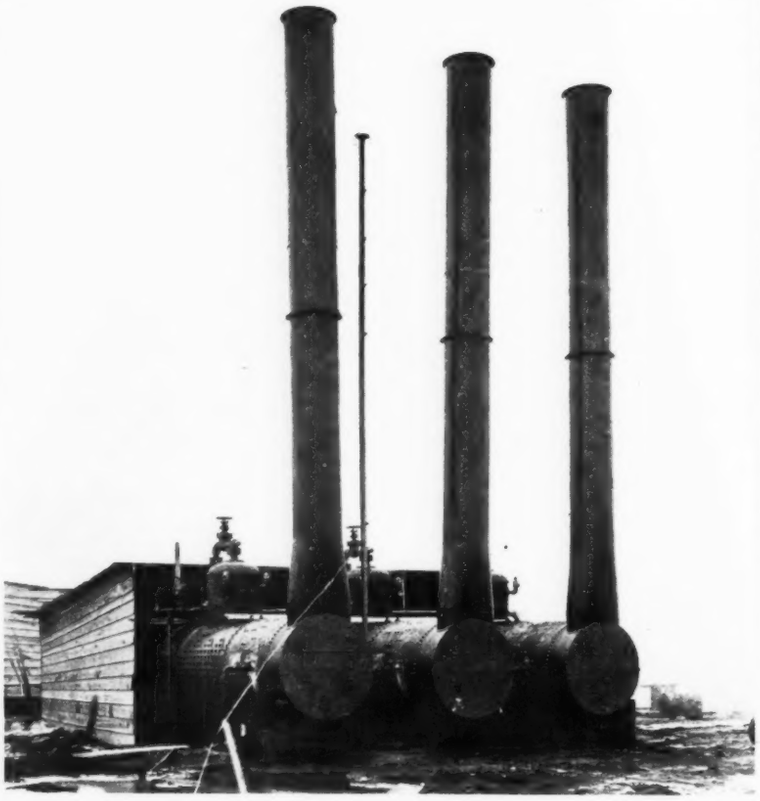
can Oil Consolidated successfully landed and cemented 6,763 feet of 13⅜-in. 68-lb. casing. Despite the enormous weight, approximately 230 tons, no trouble with the rig and other equipment was experienced in running the long string of casing. The job was completed in 18 hours and 35 minutes.

There has been a noticeable tendency on the part of many companies to use pipe of large diameter. This is because of the ease in reaching greater depths, and the saving of time by eliminating one casing string.

In the Oklahoma City field wells have been completed to 6,400 feet with a final string of 6⅝-in. casing. A number of long strings of casing of this diameter were set. Wells in the Kettleman Hills area, with a depth of 8,300 feet, are also finished with casing of this diameter. Phillips Petroleum Co. completed several wells in the Oklahoma City field with 9-in. casing. They found that in this high-pressure area of enormous flush production, that the large casing reduced friction and that the wells finished in this manner were usually larger than nearby wells completed with 6⅝-in. casing.

Improvements in drilling engines have made the rig a more efficient unit. The new steam engines are much stronger and have a more rigid main frame than the older styles. The main roller bearings are improved and the engines have heavy crank shafts. The usual steam engine is still the 12 by 12 twin design, as used during the past two years, but is fully enclosed, automatically lubricated, and is more compact and lighter in weight.

A number of wells have been drilled with gas engines, usually of 300-hp., with three used on each installation. One of these is set behind the drawworks to run that unit, while the other two are used to operate the slush pumps. Power from the engines is transmitted by texrope or chain drives direct from the engine driving end. The engines burn either gas or gasoline.



Oklahoma City boiler installation.

An increasing use of electric drilling equipment has been the result of new developments that have made the motors more suitable for rotary operation. The improvements include such features as greater horsepower, wider ranges of speed, additional safety, sturdiness in motor construction, and better adapted controllers.

While most of the electric motors have been of the alternating current type, a successful installation of a direct current unit was made in California. The power was generated by internal combustion engines using distillate for fuel. On this installation the Ward-Leonard control system is used.

A prime mover that is now the center of much attention as the result of several fine drilling records is the Diesel engine.

More wells were drilled with these engines the past year than in all the history of drilling development. Their use was in widely separated areas.

Several new Diesels were constructed during the year. These were of lighter weight and more compact, affording portability, which is necessary for field usage. Many of the Diesels used recently in drilling wells were of six-cylinder, 200-hp. construction. Fuel oil, crude oil and gas-oil were successfully used for fuel.

A feature of practically all the new drilling units has been their interchangeability, the motors operating the slush pumps and drawworks being of the same power and construction, so that in case of emergency the machines may be switched around to prevent long delays. At a well in Mexico, the drilling engines were so hooked up by clutch and gear arrangements that the drawworks engine could be used to drive the slush pumps, or the engine driving the slush pumps could be used to drive the drawworks, simply by changing levers at the rig floor control board. One engine could do both duties at the same time if desired. Special care was taken in rigging up drilling tests, so as to obtain the best possible efficiency, and also to permit easy dismantling and moving of the unit.

Drilling water supply was probably given more attention last year than ever before. Some very elaborate systems of water supply were developed in the Mid-Continent and California. In many areas it is now general practice to treat the water before it enters the boiler so as to eliminate as much corrosive action and boiler trouble as possible.

While drilling speed has been a feature of development equipment, remarkable progress has been made in drilling straight holes. In deep drilling areas most of the drilling units are equipped with some device for measuring the weight carried on the bit, it being found that by controlling the weight straighter holes were possible. Too much weight has a tendency to permit the bit to wander from a straight line. A good many companies now use surveying instruments to measure the verticality of the holes at regular intervals during drilling so that extreme deviations can be corrected before the hole becomes too crooked.

A great aid in drilling straight holes and also in preventing drill pipe collar wear is the use of pipe protectors.

Left: Vibrating mud screen in Hobbs field.

Below: Automatic weight control machine.

These are of hard rubber material and are slipped around the drill pipe, preventing it from coming in contact with the casing and also eliminating friction between the drill stem and the casing.

Rotary turntables of today are fully enclosed with an oil bath for all bearings and moving parts. The larger diameter bearings usually have double radial bearings for absorbing side thrusts of the machine when drilling, with pinion shafts of heat-treated, special steel-machined forging.

With a better grade of drilling bits, many designed for duty in specific kinds of formations, more holes can be drilled without refacing than was possible with bits previously in use. This has greatly speeded up drilling, it being unnecessary to come out of the hole as frequently as before. Both rotary and standard tools are heavier and longer than in previous years.

Because of the increased weight placed on the rig, both the crown and traveling blocks are of increased capacity. Crown block capacities have been increased to as high as 650,000 pounds, with the usual type having six or nine sheaves, with adjustable cat-line sheave. Perfect vertical alignment of wire lines between the crown and traveling block, together with a low center of gravity, has featured the construction of these units.

Drilling in the bay and bayou region of Southern Louisiana presents unique problems. One of the most difficult is that of obtaining suitable power. This has been solved in a novel manner by The Texas Company. A floating power house to supply electric energy for drilling. Two units, each consisting of a 240-horsepower Diesel engine direct connected to a 175 K. W. A. C. generator. The Diesel engines are designed for salt water circulation and are equipped with pumps and oil cooler suitable for tropical waters.

The first well drilled by electric motors supplied with energy from the power barge has recently been completed and very satisfactory results were obtained. This is further evidence of the great strides that are being made in adapting the latest power equipment to oil drilling operations.

Left: Derrick foundation corner post.

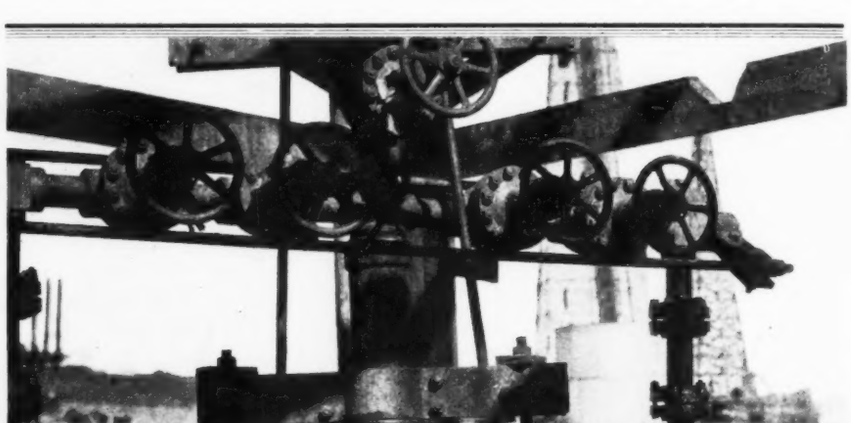
Low Pressures May Necessitate

Big Air Lift Program for East Texas

EVERY effort is being made by East Texas operators to conserve the natural gas pressure of the area. Despite their efforts, however, it is likely that the district will soon depend upon artificial means of lifting oil to the surface, as the natural pressure is very low and declining rapidly in many parts of the field.

All wells are tubed with 2½-inch or 3-inch tubing, the bottom joint perforated before completion and are equipped with adjustable flow line chokes. Such hook-ups prolong the flowing life of wells by lowering gas-oil ratios and conserving gas pressures. The choke also serves to curtail the flow to transportation and storage facilities.

Above-ground hook-ups on producing wells vary greatly. The number of gate valves and types of connections depend upon the operator. Some wells are equipped with only one control gate and the flow line gate valves, but they are exceptions, as it is customary to have two control gate valves. Many wells have an elaborate system of flow line gate valves and adjustable chokes. Gate valves are usually of 1,000 or 1,500-pound test pressure.



Connections on Humble Oil & Refining Co.'s producing well in the Bateman district.

Pressures of 300 to 500 pounds are found in the Lathrop and Bateman areas and 275 pounds in the Joiner area. Ten million cubic feet of gas is exceptionally large for a producing well in any of these areas. The well hook-ups depend upon the pressures encountered, therefore they vary widely. Wells in the Lathrop district showed a decline in rock pressure recently when tested for proration purposes. The pressure in most cases had dropped to 300 pounds or below, and in some cases was half the pressure at which the wells were completed.

Low pressures have been found in many north central and eastern Texas pools, and their ultimate recovery has been surprisingly large in many instances. This may be the case with East Texas, especially if gas lift is applied freely at once.

Two gas-lift plants are already constructed and have proven successful in increasing crude oil production. Sinclair Oil & Gas Co. has a three-unit plant on its W. W. Holland lease and has applied gas-lift to nine wells, resulting in a 15 to 60 per cent production increase. Pressures of 200 to 275 pounds per square inch were used to flow the wells, which have a total depth of 3700 feet and are tubed with 2½-inch tubing landed from 600 to 1500 feet off bottom. The average gas-oil ratio has been 500 cubic feet of air and gas to the barrel of oil. Tidal Oil Co. has a four-unit, motor-driven plant. Both of the plants are in the Joiner area.

As there is a low pressure and a large volume of fluid, together with a comparatively shallow depth, the district is ideal for gas-lift or pumping. Operators are assured that the district will not require high gas-lift pressures and that it will not need unusually heavy pumping equipment.

A number of wells in the Joiner area have stopped flowing naturally. Swabbing is necessary to revive them, although most of the wells started flowing at the time of completion. Many wells in this district are on the pump. Joiner has shown the largest pressure decline which, together with rapid development and lower initial pressure, has caused the adoption of artificial production means.

Much interest is being created by the unusually high temperatures found in some of the wells. In the Lathrop district temperatures of 132 degrees F. to more than 140 degrees F. have been registered, and the same figures apply to the Bateman pool. Not all the wells have high temperatures, some wells producing subnormal temperature oil as low as 40 degrees F.

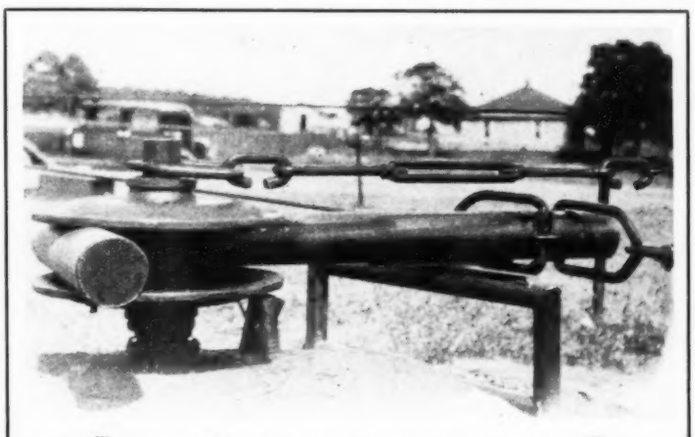
It is likely that treating compound companies will sell much material in the district. Already some companies are making sales of both compound and treating equipment.

One well that has a pressure of 575 pounds with a large flow of oil in the Bateman area has been completed in a little different method from the usual practice. The casing was set a little higher so as to leave open a conglomerate porous formation just above the producing horizon. The owners believe that this conglomerate horizon carried considerable gas and accounts for the larger pressure of the well.

Equipment Improvements

Reduce Lifting Costs at . . . Small Pumping Wells

MANY shallow wells, producing only a few barrels of oil daily, have been threatened with abandonment because of prevailing low crude prices. In many places in the Mid-Continent the margin between the lifting cost and the market price has been so small that producers of these so-called "stripper" wells have had no recourse but to exert a still greater effort to reduce their lifting costs in order to keep from operating at a loss. As a matter of fact, the recent concern of producers of "stripper" wells has been not so much with making profits as with preventing losses in their producing operations. They are satisfied if they can break even and still keep at least their older and more valued field men employed and their equipment operating. An instance of what can be done is exemplified by what the Barnsdall Oil Co. has accomplished in the last year. This company has, in the first four months of this year, been able to reduce its lifting costs about 4½ cents per barrel over the average lifting cost of 1930, on several of its shallow properties. The properties on which this reduction has been made has 298 wells, the average daily production of each of which is about 1¼ barrels.



Here is shown the type of steel swing now in use. The vertical shaft is set in concrete.

About a year ago the company made a thorough survey of the field, of the wells, their operation and surface equipment, to see what improvements could be made that would increase the efficiency of operation and make an appreciable reduction in the lifting cost and the subsequent cost of handling the oil in the field.

There are 298 wells, of which 279 produce from the Bartlesville sand and 19 from the Wilcox sand. The average depth of the Bartlesville sand wells is 1550 feet and of the Wilcox sand wells 2000 feet. The Bartlesville sand wells were drilled between the years 1904 and 1910, and the Wilcox sand wells between 1923 and 1925. Many of the Wilcox sand wells originally drilled have been plugged and abandoned because of water encroachment.

Casing in the Bartlesville wells consists of several joints of 10-inch surface pipe and a string of 6⅝-inch casing to the cap rock just above the producing horizon. In the Wilcox sand wells the well casing consists of several joints of 10-inch surface pipe, about 1600 feet of 8¼-inch casing and a string of 6⅝-inch casing to the top of the producing horizon. No cement was used in setting the casing, a formation shutoff was obtained with a shoe or a packer run on the bottom of the casing.

All wells are pumped by jacks operated through pull rods from 16 central bandwheel pumping powers, located at convenient points on the properties, with gas engines of 25-horsepower at some and 35-horsepower at others, with 16-foot bandwheels, and 10-inch and 12-inch belts. The smallest number of wells pumped by one central power is seven wells and, by the largest, 23 wells.

Sucker rods, ⅝-inch and ¾-inch, and common working barrels are used. Some wells are equipped with insert-type pumps.

Maintenance charges on surface equipment at the wells and on pull rods, were reduced, and smoother operation obtained by replacing all woodwork with steel. Jacks were thoroughly overhauled and set on concrete. Old swings, angles, holdups and holddowns, were replaced with steel types of more modern and efficient design. A lever-type counterbalance was installed on some of the heavy Wilcox sand wells, and has cut well troubles and upkeep charges to a minimum. Time pumping studies were made at the wells and a schedule worked out whereby the maximum production was obtained from each well with a minimum expenditure of power. The amount each well should be pumped each day to obtain the maximum production was determined. By this means the load on the central pumping powers was maintained uniform.

A lever counterbalance at one of the deeper Wilcox wells. It is well set up and efficient equipment of this kind that aids in obtaining the maximum production at the lowest cost.

All leases have been equipped with vapor-tight steel stock tanks. These are kept well painted and in thorough repair so as to keep evaporation losses at a minimum. An increase of about two degrees (A. P. I.) in gravity of the oil has been obtained over the previous gravity of

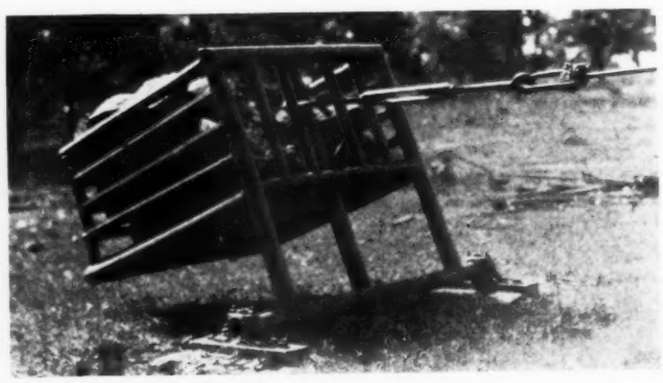
31.5 degrees A. P. I. Many of the heavy wells are equipped with a steel 36-foot mast for pulling rods or tubing, made from 8¼-inch and 6⅝-inch casing. Tractors are used for pulling rods and tubing.

Besides rod, tubing, and pump repairs, repair work on the wells themselves has been reduced. All the leases are models of cleanliness and efficiency. Everything about each well is kept spick and span, and all surface equipment is kept well painted. All this has had a favorable effect on the men on the lease. In addition to taking a pride in keeping things looking well, there is higher standard of efficiency maintained in working around the wells. Even the pumping power houses outside and inside are models of neatness and cleanliness.

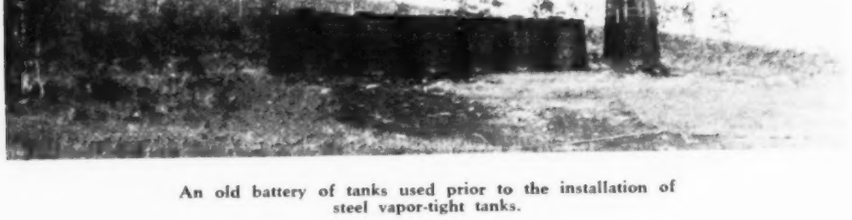
Altogether 28 men are employed on the lease to look after the 298 wells. This is 10.6 wells per man.

For 1930 the average lifting cost was 56 cents per barrel. For the first four months of 1931 the average lifting cost was 51.5 cents per barrel. This lifting cost includes only the actual cost of lease operation, that is, costs controllable by the field man in charge, as follows: Lease labor, lease supplies, teaming and tractor, operation of pumping powers, well repairs, including cleaning out, oil treating and miscellaneous expense.

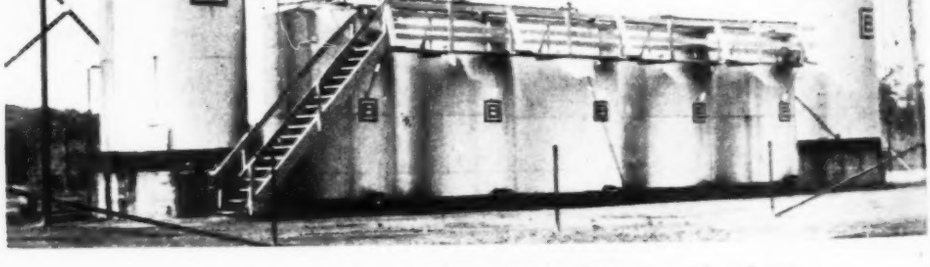
These leases are typical of many others to be found in the oil fields today. When it is considered that it is from such small wells as these, that 30 per cent of the total oil production of the United States is obtained, and that this represents probably some 150,000 wells at least, the attention that is now being given to them is more than justified. Reduced costs in operation of wells of this kind are of the more permanent type and are well worth while.



Stone boat of welded construction used on small wells.



An old battery of tanks used prior to the installation of steel vapor-tight tanks.



Here is a battery of vapor-tight steel tanks. Note the spick and span appearance of the equipment.

Review of Progress in PRODUCTION PRACTICE

By K. C. SCLATER

A REVIEW of the progress and trends in oil and gas production practice during the past year is in some respects a reflection of the protracted difficulties of overproduction that have continued to beset the industry. Harassed by low crude prices and the necessity for drastic curtailment, the producer has been driven to make analyses of his costs in such detail that he is acquiring a new perspective of his operations. With what result? New standards of efficiency in oil-producing operations are in the making.

Most producers have begun to recognize the fact that the adoption of proper methods of well control and good equipment are necessary to obtain a low lifting cost, not only during the flush stages of production but during the entire life of the well or property. A new flowing well in the flush stage of production is given the same scrutiny in regard to its present and future lifting cost as the old pumping well whose most productive years have passed. The method of producing a well is thought of in terms of its whole life rather than its immediate future. In the past it has, more often than not, been customary to concentrate attention on maintaining a high daily rate of production and neglect the factor of future lifting costs. Today the producer, in considering the method and equipment that should be employed to produce a well, is more inclined to take a long-range viewpoint, especially in regard to deep wells, for he realizes that on these, lifting costs are likely to mount high. Failure to conserve the rock pressure and the gas in deep productive areas will result eventually in lifting costs taking a sharp upward trend.

This changing outlook has been largely responsible for the improvement in methods and equipment for the closer control of gas-oil ratios, for the increasing use of tubing in wells, and for the trend toward the practice of bringing in wells through tubing, particularly in the Oklahoma City field.

A recent development that has attracted much attention is the new technique and equipment for running tubing in a well under pressure, while the well is flowing under complete control. Although this practice is of recent adoption, having been developed and methods perfected several years ago in Louisiana to tube high-pressure gas wells, its use has spread quickly to oil and gas wells during the past year. A number of producing wells in widely scattered areas have been tubed by this method, including wells in the Yates field, the Big Lake field, the Gulf Coast fields and the fields of the Panhandle district, Texas, and the Oklahoma City and Seminole fields of Oklahoma.

Two-stage separator hook-up with low-stage separator elevated.

In Yates field many wells which were tubed under pressure have shown a sharp reduction in gas-oil ratio when placed on tubing flow. All the deep producing wells in the Big Lake field have been tubed under pressure during the last seven months. Strings of 2-inch, 2½-inch and 3-inch high tensile alloy steel tubing more than 8,000 feet long were installed while the wells continued to produce. The tubing of these 8,000-foot wells is an indication of the rapid progress, and a significant trend, in deep-well production practice.

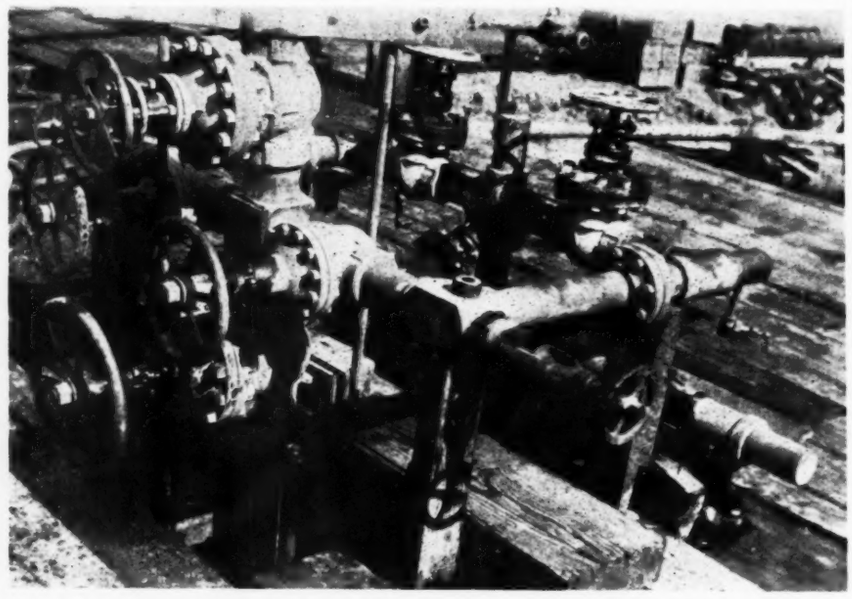
Running tubing in wells under pressure has also been pioneered in Californian fields by the Union Oil Co. of California. About a year ago, in a well in the Santa Fe Springs field, the tubing was lowered from 5,000 feet to below 7,000 feet while the well was flowing by gas-lift. One of the main reasons for developing this novel method and designing the necessary equipment was to eliminate high kick-off pressures in gas-lift wells. This is done by running tubing to a depth that will not require too high a kick-off pressure, and then establishing flow in the well; the tubing is then lowered in easy stages to any desired depth without interrupting the flow of the well. The equipment used consists of an arrangement of tubing control heads, valves and connections, whereby the flow from the well can be by-passed as each stand of tubing is added. The method can be used either to raise or lower the tubing in a gas-lift or a naturally-flowing well, causing practically no interference with the flow of the well.

Tubing control heads designed for high pressure and of sturdy construction to withstand the severe working requirements have contributed to the progress made in tubing high-pressure wells. Two, and sometimes three, tubing control heads are used to tube a well under pressure. These are mounted in the casing, usually above the master gate.

"Snubbing" heads have been designed for "snubbing" in the first few joints against the well pressure. A wire line, both ends of which are attached to lugs on the traveling snubber, is run through snatch blocks securely attached to the derrick foundation, thence to a pulley on the traveling block. A single line is used so as to equalize the pull on the traveling snubber, which has inverted slips fitted with springs to allow the passage of the tubing couplings.

In tubing high-pressure wells it is usually necessary to "snub in" the first few joints of tubing. A pneumatic snubbing jack specially designed for running tubing against the well pressure has been in successful use in the Gulf Coast fields, Texas, and is the most recent development in this type of equipment. It is designed to operate either on compressed air or on high-pressure gas from the casinghead.

Another interesting development in connection with running tubing under pressure is the detachable plug used on the bottom of the tubing as a seal while the tubing is being run. It is held in place by the well pressure while running in. After all the tubing is in and the well connected up, the plug is released by building up a pressure inside the tubing sufficient to overcome the pressure at the bottom of the well holding the plug on its seat. This method is safe and positive and much in advance of the old method that necessitates the breaking of a disc.



Well-designed Christmas tree with control head below water level in the cellar.

Progress in tubing high-pressure wells has been accompanied by a revival of interest in bottom-hole chokes. The most recent development is a bottom-hole choke that can be installed or removed without having to pull the tubing. It is not of the adjustable type, but the fact that it can be run on a measuring line and quickly changed does not make the non-adjustable feature a serious drawback. Although it is called a bottom-hole choke, the most recent design can be inserted at any desired depth in the tubing. This is an advantageous feature, as it permits of a still wider range of well control.

Tests on bottom-hole chokes are in progress in Hobbs field, New Mexico; in Yates field and Raccoon Bend field, Texas, and in Oklahoma City field and Seminole Field, Oklahoma.

According to H. C. Otis, who has been actively co-operating in these tests, the bottom-hole choke being used is one recently developed by the Southern States Co. It is run and pulled under pressure on a Halliburton steel line, and may be set at any desired depth in the tubing string. The bean is of fixed diameter. To change it, the choke is pulled and a bean of the desired diameter inserted and the choke rerun to the desired depth. In the Yates field, Texas, changes in bean diameter or in choke depth have been made by experienced crews in an hour, including time for moving to the well, rigging up, pulling the choke, changing the bean, rerunning and setting. In the Oklahoma City field, where more time is required for rigging up because of the higher pressures, about half a day for a crew of two or three men is necessary to make a change. The removable feature permits taking the choke from the well when potentials are to be taken. In the Oklahoma City field the same choke has been set in 3-inch tubing in five different wells. In one well in the Yates field five different bean diameters have been tested. In another well in this field the choke has been set at four different depths. Flow through the tubing is shut in during the running and pulling, so that the well volume and pressure have little effect on these operations. The choke was handled in the 6,500-foot wells in Oklahoma City field with almost the same ease as in the shallower wells in the Yates field. The main object of the tests is to lower the gas-oil ratio by an adjustment of flow velocities in the tubing that will establish optimum flowing conditions in the well.

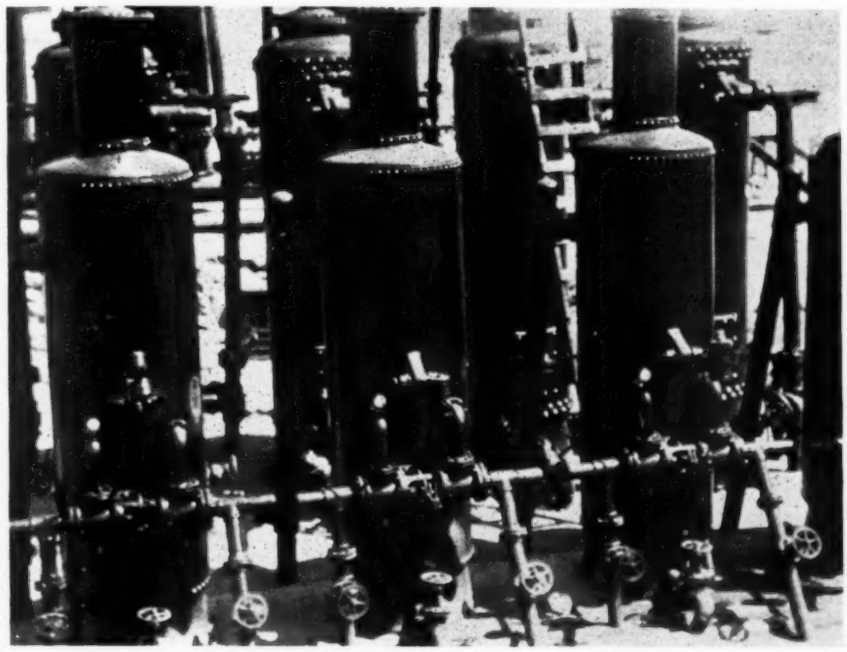
Several advantages should accrue from the use of a choke that can be inserted at any point in the tubing. One important one is wider range of flowing conditions can be covered without too frequent changes of size of tubing string. Another progressive step to make more flexible the control of flowing wells is the combined use of a low-pressure surface choke and a bottom-hole choke. So variable are the well conditions met with in actual field practice that any method that will permit a wider range of adjustment of flowing conditions in the well is most desirable, and this the combined use of the low-pressure surface choke and the bottom-hole choke provides. By changing the surface pressure only a few pounds in a flowing well of low delivery pressure choked at the bottom, a more efficient delivery velocity, hence a lower gas-oil ratio, can be obtained without seriously affecting the flow into the hole. This combination use of chokes is also equally effective in establishing efficient flow conditions in wells that have reached the "heading" stage.

Serious trouble with sand in the Oklahoma City field was responsible for introducing the use of screen pipe and perforated liners in this field. Casinghead fittings that became badly sand-cut set up a serious hazard. After a study of the sand conditions and the character of the sand itself, screen pipe was run in many wells in the field. While this was something new in Oklahoma oil field practice, the installation of screens and perforated pipe in wells as standard equipment is common in other fields. Screen pipe and perforated pipe has been the subject of much study, particularly in the Gulf Coast fields, Texas, and in the oil fields of California. The choice of the proper size and type of screen in these fields is an important matter.

There are types of screen pipe now available to combat almost every known sand condition, and it is owing to this fact that the use of screen pipe is becoming more general.

Many different types of surface equipment have been designed to cope with sand in the Oklahoma City field. Elaborate systems consisting of combination sand traps and gas-separators have been devised and put into use. It is during the taking of potential tests that this surface equipment has proved most effective.

Gas and oil separation is becoming an increasingly intricate problem in high-pressure fields. Improvements in the design and construction have greatly increased the efficiency and capacity of gas separators available on the market today. Big demands have been made of this type of equipment, particularly in the Oklahoma City field and in the Kettleman Hills field.



Part of the gas trap installation on a Kettleman Hills well.

Refinements in design and the arrangement of gas-trap installations at the well so as to obtain greater use of the energy of high-pressure gas are factors that are receiving ever-increasing attention.

Pumping wells and their equipment have been the subject of serious investigations. Operations have been analyzed from every conceivable angle to ascertain where worthwhile improvements could be made.

Slow-speed pumping has shown interesting possibilities on moderately deep and small wells. Pumping small wells at a profit has always been a problem. A big stride toward its solution is the adoption of slow-speed pumping methods. Slow-speed pumping units of the auxiliary gear and the cam shaft type have been designed and show successful results in use. Speeds as low as six-tenths of a stroke per minute have been used on a 15-barrel well. On a 50-barrel well in California the same production was obtained at ten strokes per minute as at 39 strokes per minute, and the power cost reduced 50 per cent. In addition, maintenance costs on rig and pumping equipment were lowered.

High volumetric efficiencies have been obtained on wells in California with constant-velocity cycle pumping units. This unit was developed largely as a result of slow-speed pumping investigations. Operating at a speed of only seven-tenths of a stroke per minute, with a 36-inch stroke, and pumping from a depth of 2,200 feet, a volumetric efficiency in the neighborhood of 90 per cent was obtained. Substantial increases in production of from 50 to 300 per cent have also been obtained, as well as a high volumetric efficiency. One of the most advantageous features of slow-speed pumping is the reduction of lifting expense due to lower power costs and reduced wear and tear on equipment.

Much progress has also been made in pumping deep wells. Sucker rod stretch, counterbalancing, pumping speed and prime movers have all been studied and their effects on deep well pumping operations observed. Latest data from the field show that with pumps using sucker rods, wells can be successfully pumped from depths of 5,500 to 7,000 feet. At least one well is reported to be pumping oil successfully from a depth below 7,000 feet with an insert pump and sucker rods. One company in California is pumping a large number of wells from a depth of about 5,500 feet with insert pumps, using ¾-inch sucker rods, and is having very little sucker rod trouble. Proper counterbalancing and good surface equipment are partly responsible for such good results. It also speaks well for the high quality of the sucker rods in the well.

Heavy fluid loads are encountered in many deep pumping wells. An insert pump decreases the fluid load on sucker rods because of its small cross-section.

A development worthy of note in prime movers for pumping wells is the installation of 50-horsepower slow-speed oil engines in several fields in Texas for pumping moderately deep wells of several hundred barrels daily production. Remarkable ease in starting and low fuel and maintenance costs are the important advantages that these units have shown since installation. The interest that attaches to these engines is that power costs in pumping are being given more attention than in the past and the selection of a prime mover is usually based on accurate data pertaining to the conditions under which the prime mover will be required to operate. It is for this reason that the adaptation of the slow-speed oil engine and engines of the Diesel type for pumping wells is attracting attention.

The pressure at the bottom of a well has an intimate relation to all problems of oil recovery and good well operation. Several bottom-hole pressure recording instruments have recently been devised. One of these, the Amerada pressure gauge, a pioneer instrument of its type, is small enough to be run in tubing and has been in use for about a year in the Mid-Continent fields. It is fully described, together with a discussion of the results obtained by its use, in a paper by Millikan and Sidwell that appeared (through the courtesy of the A. I. M. E., New York) in the May issue of THE PETROLEUM ENGINEER. From this paper can be glimpsed the possibilities and utility of such an instrument in analyzing conditions in a well.

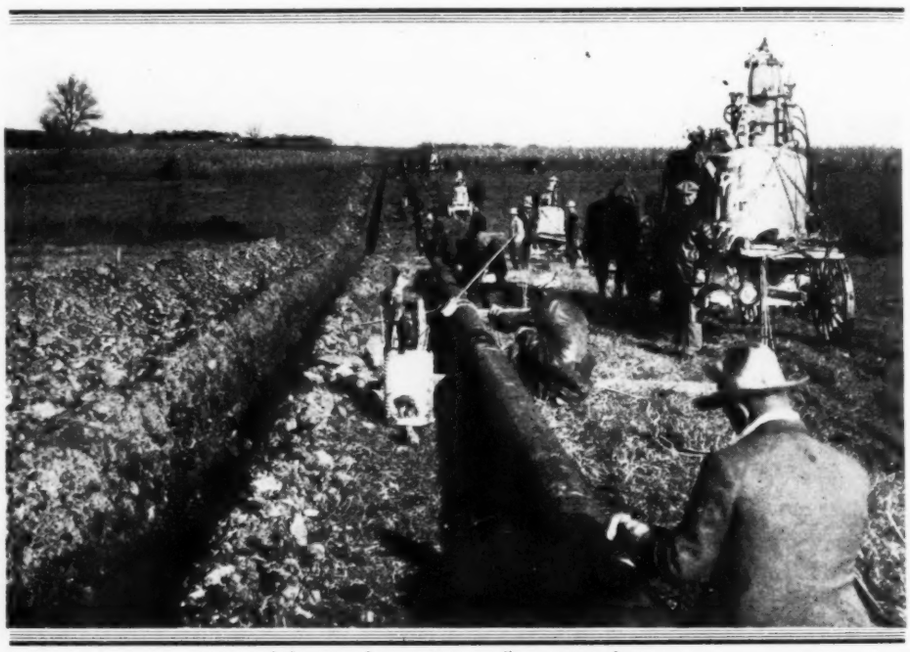
Many companies are adopting individual well cost accounting systems, as it is only by some such system that individual wells can be checked and the sources of loss arising from defective equipment quickly detected. This system is especially effective in tracing sources of loss on old leases of settled production and small wells.

Developments in Pipe Line Construction

By J. H. DAMERON

A FEW years ago the building of great pipe line systems, such as those constructed during 1930, would have constituted an economic impossibility. Adequate materials were not available, nor were construction methods as efficient as those of present times.

When the industry was offered larger diameter, lighter weight and stronger pipe, it only followed that manufacturers designed improved equipment as the contractors and construction men devised speedier, more reliable and more economical methods of laying pipe. These advancements not only met the problems connected with building large diameter and long lines, but also reduced costs so that it opened the avenue to one of the greatest periods of pipe line construction known to the oil and gas industry.



A battery of generators on line construction.

The year 1930 contributed greatly to the building of reliable pipe lines. Improved methods of joining pipe, cutting trenches, crossing streams, and handling materials in the field are only a part of the remarkable progress witnessed last year.

Large diameter and high tensile strength pipe has been available for several years. Last year the first seamless pipe larger than 13⅜ inches in diameter was developed and during the several hundred miles of this type of pipe, up to and including 24-inch diameter was used in the construction of natural gas lines. During the same period several other companies making seamless and lap-welded line pipe expanded their mills in order to meet demands for electrically welded material.

With the building of these huge arteries which wind their way into all but a handful of states in the Union, more reliable methods of making joints have been developed. In the acetylene welding field, welding rods have been developed making it possible to have welded joints as strong as the pipe itself which has an ultimate strength greater than 70,000 pounds.

Experiments have been carried on for a number of years with a view of developing mechanisms for automatic welding in the field. A new type of blow pipe has been designed which permits semi-automatic welding and eliminates to a great extent the human element in welding large lines. The welding rod is supported in a holder attached to the frame of this device. One of the flames of the new blow pipe preheats the rod and the other brings it to the melting point and heats the parent metal. The device is so designed that the rods feed by gravity into the weld.

The chill ring, long used in arc-welding, was brought into use in connection with acetylene welding of pipe lines last year. It is a thinner ring than that used for arc-welding and its primary purpose is to insure having the weld fuse the full wall thickness of the parent metal and eliminate "icicles" inside the pipe.

In the arc-welding field faster burning and improved rods were developed. These rods, likewise, produce a weld with a tensile strength equal to metal in the walls of the pipe. The generators for this type of work also were featured by numerous refinements.

In the equipment field the versatile tractor leads the parade of improved pieces of construction machinery. Its uses start with right-of-way clearing gangs, and is concluded with the backfill. So many uses have been developed for this mobile unit that it is hardly possible for a large line to be built without a fleet of them crawling over the rough country, and they figure in almost every phase of construction. They are sturdier and more reliable with enclosed working parts tending for safety and better lubrication. The accessory equipment permits a single tractor to bend pipe. Others have been arranged so they may work in pairs, permitting a small diameter line to be cleaned, painted, wrapped and lowered in a single operation. Embracing still more territory, special graders have been designed which permit them to be used in making excavations at pipe line stations.

Ditching machines of the past year also show some improvements in design. They are sturdier, more powerful and cut a cleaner trench. The latter item is of extreme importance in the construction of the large diameter lines where the bending stresses caused by the contour of the

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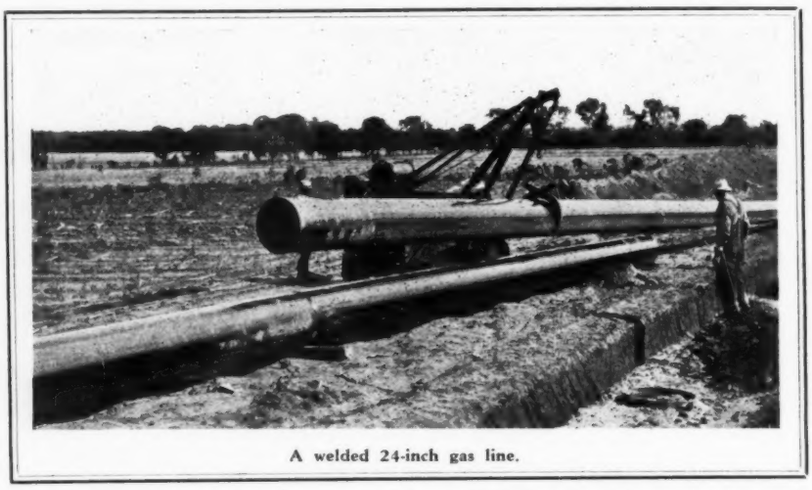
ground are not minimized. With a more uniform ditch less strain is set up in the large diameter pipe.

Contractors are using these machines to a greater extent during wet weather or in muddy fields. When the ground is soft the crawlers are widened by bolting board extensions to them and when this is insufficient, plank track is laid in order that the machines may go on through.

If this method fails in country where trouble is experienced with caving ditches, it has often been found economical to dig the trench through such a section with one of the clam shells usually accompanying each job. These also are used in cutting a trench in some stream crossings as well as digging the approach for such crossings.

The huge power shovels, likewise, are being utilized for wider range of use. Both a light type for work in extremely hilly country, and the more powerful type have been developed for aiding in clearing the right-of-way and cleaning out trenches which required blasting.

Methods of blasting rock also have been greatly improved to the extent that this phase of ditching is accomplished with less blasting material. The shots, too, are so loaded that the explosion partially cleans the trench and leaves the remainder of the rock so shattered that it is much easier to remove. This improvement in blasting is due a great deal to the entrance of explosive engineers in the pipe line construction field. In the swamp country, where it was necessary to blast stumps, the recently developed methods have resulted in substantial savings over former hit-or-miss method of placing varying numbers of sticks of dynamite beneath the stump. The bending of large diameter pipe by fire is an art being rapidly developed. Fire bending, of course, is not new, but it is only recently that this phase of construction was developed to a point where a bend could be made with sufficient accuracy to eliminate bending stresses after the pipe was lowered. With improved methods the flames are literally wrapped around the joints at the point of the bend. The bend is slowly made after the pipe is heated to a temperature where it will contract easily at one point and "stretch" at the other without buckling. Many crews are so expert in fire bending that it is possible for them to make a bend conform almost accurately to the contour of the ditch and closely enough to eliminate bending stresses.



A welded 24-inch gas line.

It is common practice for many companies to use fabricated pipe rather than fire bends. This is especially true on 26-inch diameter lines. Last year many such "tailor-made" bends were shipped to the fields and welded into the line. When a bend of small degree is required to take car of the unconformities of the ditch or the contour of the country the sleeve type coupling is used to care for this condition. This same type of coupling is also used to care for contraction and expansion of the pipe due to temperature changes.

Equally progressive strides have been made both in the development of protective coatings for lines and in their method of application. Castings that will not only withstand corrosive attacks of the soil, but coatings which stand up better under soil stress have been developed. This latter phase of pipe protection is improved greatly with the use of many types of wrapping applied over the coating. The newer types of coating permit their application in cold weather without fluxing, which greatly decreases their resistance to mechanical destruction. When unfluxed coatings are applied and crack after application, the cracks have been successfully sealed by brushing flux over the surface before water entered the cracks. This process sealed over the openings, and they healed completely after being buried.

Newer methods of application have not only accelerated coating of pipe, but have effected important savings in coating. One of the most common practices of applying paint is with a rolling rig, which permits the pipe to be rotated as the coating is applied. Much work is being done to develop methods of spraying coatings on the pipe. It is common to find various devices on the line to spray the priming coats, but the present devices for spraying the heavier coatings are just beginning to reach the market. Such methods insure a more uniform application and at the same time eliminate the waste connected with the sling method of application.

Greater care is shown in lowering the pipe into the ditch. The tongs or slings used by tractors in lowering pipe are so protected that they will not break the coating on the pipe as it is lowered into the ditch. Lowering, too, is now handled in such a way as to relieve as much as possible the temporary stresses imposed on the joints when the pipe is raised off the skids and then lowered in.

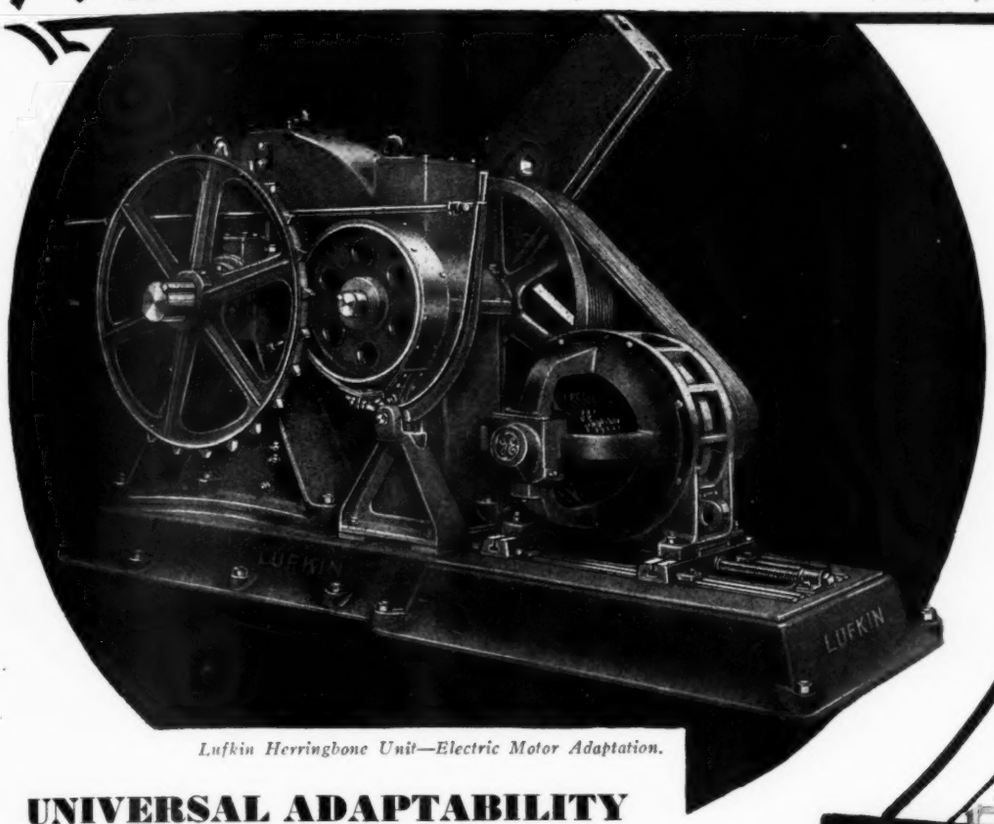
The back filling job, likewise, is accomplished more rapidly and efficiently with the new type of back filling machines. Varied types of bull dozers were introduced last year, to be attached to tractors which may be used for back filling.

The newer types of air compressors are more reliable in operation and a wider field of work has been found for them other than their use in drilling in rock or building up pressure in the line for a test. New cleaning tools, operated by air pressure, have found their way into pipe line construction. These grind off mill scale and mill paint, producing a bright finish in far less time than was formerly required to clean pipe by hand. Pneumatic tools are also being developed which will permit a more rapid tightening of bolts on the bolted type of couplings. The portable type of compressors, too, are used to build up pressure in tanks used for spraying coatings on the pipe.

Another phase of line construction that gained wide prominence last year was the bridging of streams for the purpose of carrying lines over them. This has been particularly true in streams that have been difficult to cross with the submerged type of crossing. The advantage offered by the bridge is that the line is accessible for repair in the event of a break and the construction costs of the two types of crossings are approximately the same.

The submerged type of crossing, built of river pipe with welded joints and made more rigid with heavy and close-fitting clamps, predominates as a general type of stream crossing. More rigid inspection of the stream crossing and

ADAPTABILITY



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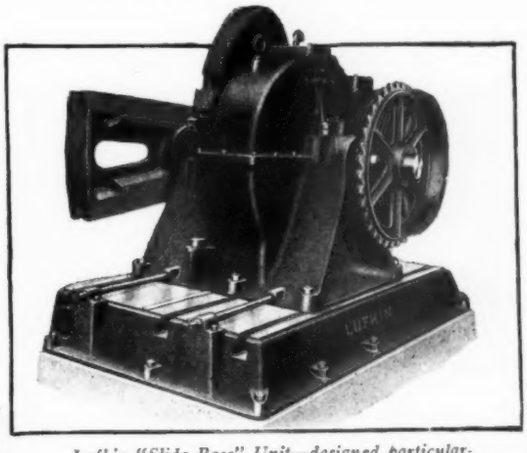

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improved methods of construction and procedure is permitting the building of a crossing with less stress on the multiple lines and with the assurance that the lines will remain in place over a longer period.

Station construction is in step with the progressive march of line construction. For the most part the newer stations built last year were made with structural steel and corrugated iron. These permitted the easy expansion of the building in the event of the necessity of more units. A great many stations also were built with brick and these too were designed so that expansion could be taken care of at a minimum cost.

One of the notable features of station design is the simplicity of piping and the full and semi-basement type buildings to make the engine piping more accessible. Piping for the suction and discharge lines is invariably featured by a more simplified layout requiring less pipe, which may be easily reached without disturbing other lines or will permit the expansion of the station at a minimum cost. In the full and semi-basement type stations all of the engine piping is open to instant inspection, marked for instant identification and easily accessible for repairs.

The units in the gas compressor plants have many new refinements lending themselves to more efficient and sustained operation and in the case of some of the smaller sized compressors, the horse power has been doubled without any more material increase in the size or the weight of the unit. The Diesel-powered stations, with new units, also show machinery of greater horsepower, higher efficiencies and lighter weight.

Remote control pipe line stations became a reality last year with the installation of two such plants in the Mid-Continent. These plants, consisting of more motor-driven centrifugal pumps, are operated from a key station located many miles distant. They are equipped with protective devices to automatically shut down the plant in case of major trouble and other devices indicating the approach of other trouble, such as hot bearings or rapidly filling sump tanks. Such stations operate in connection with motor-driven gates. The last year witnessed the first serious consideration on the part of pipe line companies to install centrally located generating plants. These would be used to furnish power to main line stations or new lines whose station equipment consisted of motor-driven reciprocated or centrifugal pumps.

The first efforts to drive centrifugal pumps through speed increasers was made last year when one of the three major gasoline lines constructed last year, used Diesel engines to drive centrifugal pumps in this manner.

A new type of gas compressor made its appearance during the year when a motor-driven high speed centrifugal compressor was designed for use in an Ohio gas booster station. This machine works much under the same principle as does the centrifugal pump.

A new type of valve control was also developed during the year which affords automatic operation for gate valves on the main line or at header gates. This type of valve is operated by pressure variations, opening when under pressure and closing when pressure drops off the line. It requires only line pressure. Thus, if this equipment is installed on a main line valve it would immediately close when a break occurred and would continue to operate as a relief valve until pressure at the station was reduced.

The use of instruments is becoming wider in the pipe line industry, both the recording and indicating type being used on pressure and vacuum lines and instruments for the measurement of gravity and volume are being used generally. These are also being used in the detection of leaks on the main line and in checking engine or machinery performance at the station.

To summarize the progress of the past year, it may be said that the great improvement in materials and methods is another step toward more economical construction and operation and further paves the way for the expansion of the oil industry's titanic transportation systems.

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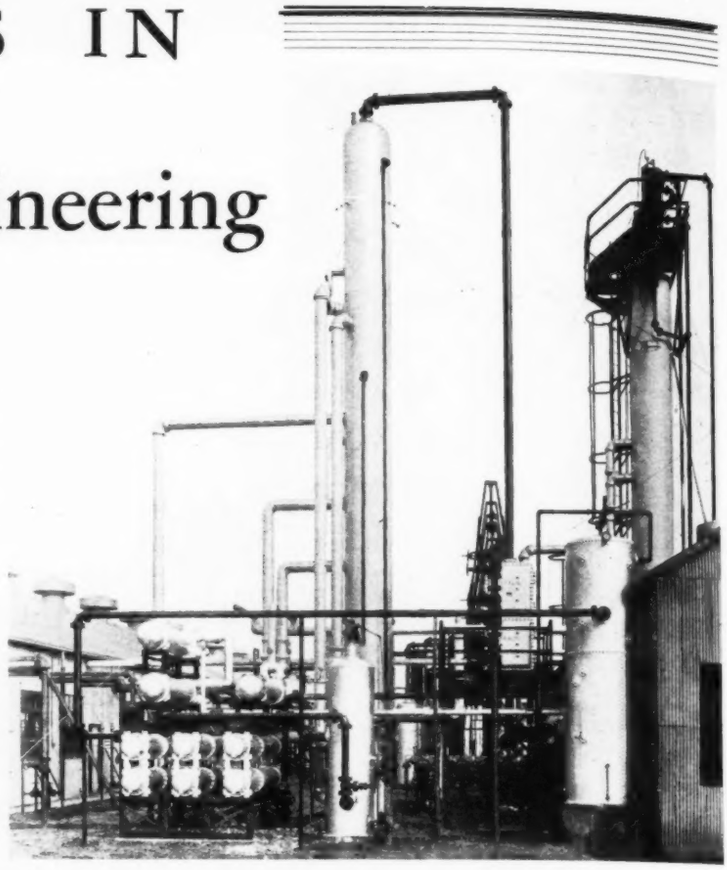
PROGRESS IN Refinery Engineering

By F. R. STALEY

MANY new units and complete refineries were constructed in the United States and in foreign countries by American engineering companies during the past year. The trend is toward larger capacity units that are operated almost entirely automatically and continuously. The design and construction of these more efficient plants, possessing sufficient flexibility to meet variations in the products desired, requires a highly specialized organization.

Some of the refineries recently built in this country are the Gulf Refining Company's at Pittsburgh and at Cincinnati, the Pure Oil Company's at Toledo, the Continental Oil Company's at Denver, and the Republic Oil Company's at Texas City. Many new skimming plants have been erected in the East Texas field. Most of these have a daily capacity under 5,000 barrels.



Sinclair gasoline plant at Maud, Okla.

Almost every refinery in the country has installed new units or equipment during the past year in order to minimize operating costs and to improve their products. Scientific research and co-operation with engineers of the automotive industry have brought about new standards and new specifications for motor fuels, lubricating oils, and other petroleum products which are based on actual performance tests. The true merits of these products are better understood than ever before.

A gasoline possessing a high anti-knock rating, and the proper volatility has become recognized as a superior motor fuel, and sells at a premium. Consequently, refiners were required to improve the knock rating of their gasoline. The uniformity and superiority of Ethyl gasoline is now so well recognized by the motorist that the wide-spread demand for it has been met by most refiners. The Texas Company, the Gulf Refining Company and the Shell Petroleum Corporation are some of the refiners licensed more recently to blend Ethyl gasoline.

Since cracked gasoline, especially that produced by a vapor phase process, usually possesses a better anti-knock rating than a straight run product, a new significance has been given to cracking: Nicely fractionated naphthas from the crude are blended with cracked gasoline to improve their knock rating. Many new cracking units have been constructed during the past year. The Pure Oil Company's new refinery at Toledo consists entirely of Gyro vapor phase units. Some refiners have installed the combined topping and cracking unit since it produces a gasoline of high anti-knock rating, and is usually very economical to operate.

Remarkable progress has been made in tube still and furnace design for both cracking and crude oil distillation units. Greater capacities per dollar of investment and higher thermal efficiency have resulted. The tube type heater permits great flexibility in the application of heat to the oil. The most effective rate of heating can be maintained to best accomplish the required results. Radiant heating sections in the furnace are now used to furnish the oil with the greater part of its total heat input. Heat transfer rates have been greatly increased by raising the oil velocity through the tubes. Proper furnace design and combustion regulation are of the utmost importance for the most successful and economical operation of a cracking or distillation unit (especially when applied to lubricating oils). Many refiners have found it very profitable to consult specialists, to have surveys made of their plants in order to improve combustion conditions which often increased through-put and improved products. Very often such fuels as acid sludge, pulverized petroleum coke, or stripped gas is used for fuel in the refinery. In many cases the application of these various by-products as fuel has been so well worked out by the use of proper combustion equipment and automatic control devices that the operation of the unit or its products are not impaired.

Numerous vapor recovery plants and stabilizing units were installed by refiners during the year. These modern plants are highly efficient and since they are practically automatic in operation through the use of control devices and instruments, little or no additional operating labor is required in the refinery. The stabilization of gasoline eliminates vapor locking tendency.

For the distillation of crudes containing good lubricating fractions, a large number of two-stage large capacity distillation units have been installed. The tube type still is used with two fractionating towers. The light fractions are flashed off and fractionated in an atmospheric pressure tower and the heavy portion is further heated in the second stage coils and flashed off into a tower under reduced pressure. By carrying a high vacuum on the second tower all of the lubricants are vaporized, producing an overhead

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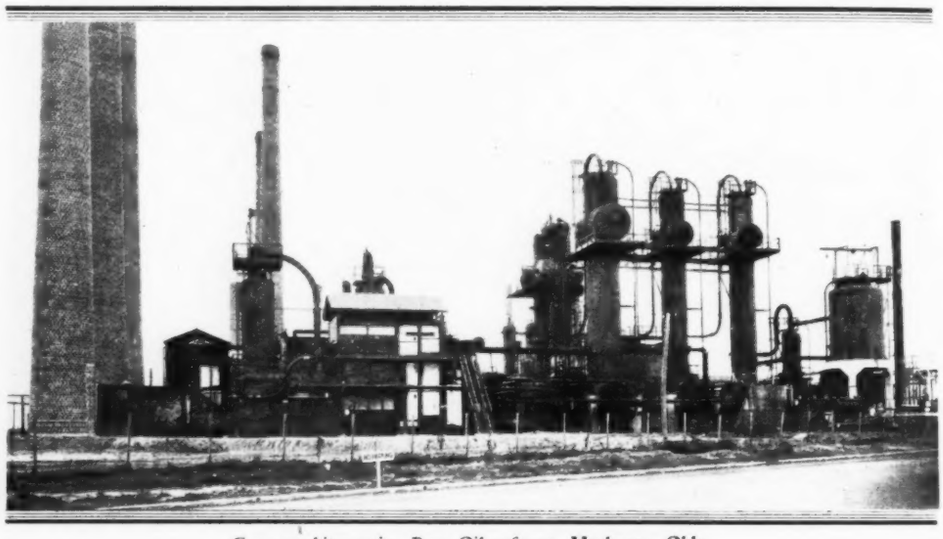
stock. The asphaltic compounds are drawn off as a tarflux. It ranges from three to 10 per cent of a mixed base crude. The overhead stock usually requires less acid for treatment and the treating loss is reduced.

The pipe still is generally replacing the shell still for rerunning and reducing purposes. Better quality products and greater yields are obtained. The vacuum still has demonstrated its superiority for rerunning pressure distillate. Since the oil does not have to be heated so much the finished product is superior and requires less treatment.

Efficient fractionation of both light oils and of the heavy lubricating ends is now regarded as extremely important. It has been demonstrated that anti-knock properties of the various fractions of straight run gasoline vary considerably. The fractions in cracked gasoline of different boiling ranges may require different chemical treatment. In the case of the lubricating portion of the crude, the character of the waxes change with the boiling point, and by close fractionation wax removal by a given process is more readily accomplished. Larger and more efficient towers have been developed to allow flexibility for variation in crude oil charged and products desired. The bubble cap column is regarded as the most efficient type, and is most widely used.



Gyro cracking units, Pure Oil refinery, Muskogee, Okla.

Engineers and physicists employed by the various manufacturers of instruments and mechanical devices have succeeded in developing and improving recording and control instruments. Accurate temperature, pressure and rate of flow control are absolutely imperative for the successful operation of the modern high capacity complex refining unit or natural gasoline plant. Liquid level controls, pressure regulators and other automatic devices have been improved so that their reliability can be so accepted that the modern plant is almost automatic in operation.

Heat exchange equipment is extensively used in all distillation units. Improvements in design and mechanical construction, and the use of suitable materials have extended their application for higher pressures and temperatures, and for resisting corrosion.

Vapor phase treating for stabilizing gasoline and removing the undesirable gum content is being more generally recognized by refiners as the most satisfactory and economical method of treating cracked gasoline. The process eliminates acid treating and rerunning which often destroys valuable anti-knock properties. It can be used in connection with any type of cracking unit. Many new Gray tower installations were made during the past year. In the preparation of Ethyl gasoline a blending stock of high anti-knock rating and very low gum content is desirable, consequently a cracked gasoline treated in the vapor phase is a very desirable material for the purpose.

Sodium plumbite is most widely used for sweetening. The chemistry of the process is now better understood than ever before. More attention has been given to the use of ammonical copper sulphate solution, and several refiners are now using this method.

Most refiners manufacturing paraffin base lubricating oils are now removing all of the wax. The centrifuge is most widely used for dewaxing long residuum and bright stocks. The oil is usually chilled to a temperature of about minus 45 degrees F. in naphtha solution and then centrifuged, which removes the wax from the oil. The use of special solvents to precipitate the wax from the oil has been used only by a very few refiners.

Metallurgists have developed many new alloys which are resistant to corrosion, erosion and high temperatures. Many of these alloys are used by refinery engineers in the construction of equipment. The use of iron chromium nickel alloy to resist corrosion at high temperatures and pressures has been used with much success for cracking oil tubes. A great deal of research work is still in progress in the development of alloys for refinery use. Non-ferrous alloys are widely used to combat corrosion at lower temperatures. Heat exchanger tubes are very often made of alloy-containing copper. Many alloys are now available for refinery service. No single alloy can be most economically used in a great variety of applications. Proper care and attention must be given to the problem of selecting the most suitable alloy for the purpose, many factors must be considered, such as physical properties, expense of machinery, whether or not it can be welded or worked, etc. A large manufacturer of pressure vessels has developed, after several years of research, a method which permits the lining of entire vessel interiors with a corrosion-proof alloy. The construction employs sheet alloy bonded to the carbon steel, so as to make the lining an integral part of the vessel wall, including heads, manways, nozzles, et cetera. Three large cracking still vessels are now in high-pressure high-temperature operation. Each is lined with 12-gauge chrome nickel iron. The particular alloy to be used in each case for the lining of a pressure vessel depends upon the service it is required to meet. The success of the lining lies in the bonding method, which makes the sheet alloy practically an integral part of the vessel.

This development is of great importance to the refining industry in combatting corrosion, when considered not only from a technical viewpoint but also in the light of economics.

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During the past year much attention has been given to the problem of storage tanks for volatile liquids. The old

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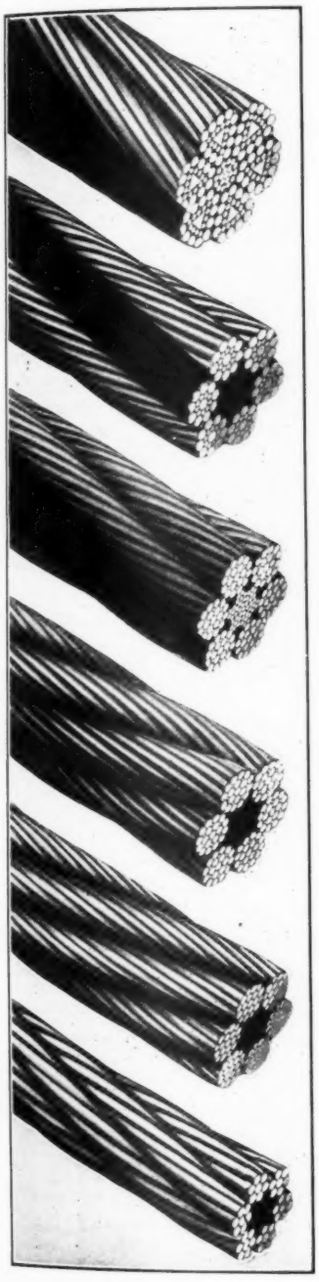

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type of metal or even wooden roofs is being discarded. The modern vapor-tight steel roof and the floating and breather type tank roof is being more extensively installed. A new type of spherical tank has been designed for pressure storage of volatile distillates, which would involve excessive losses in ordinary tanks. The floating roof type of tank reduces filling and breathing losses from working tanks. The breather roof is designed especially for standing storage tanks. Breathing losses are avoided, as the roof flexes up and down to accommodate thermal expansion and contraction without allowing the vapor to escape.

The first hydrogenation commercial plant was completed during the past year. This plant permitted runs to be made on an actual commercial scale. A great amount of technical data was collected. Haslam and Russell summarize the major adaptations of hydrogenation as follows:

1. The conversion of heavy, high-sulfur, asphaltic crude oils and refinery residues into gasoline and distillates low in sulfur and free from asphalt, without concurrent formation of coke.
2. The alteration of low-grade lubricating distillates to obtain high yields of lubricating oils of premium quality as to temperature-viscosity relationship, Conradson carbon, flash and gravity.
3. The conversion of off-color, inferior-burning oil distillates or light gas oils into high-gravity, low-sulfur, water-white burning oils of excellent burning characteristics, with gasoline being the only other product except for a slight gas formation.
4. The desulfurization and color- and gum-stabilization of high-sulfur, badly gumming cracked naphthas.
5. The conversion of paraffinic gas oils into low-sulfur, gum- and color-stable, good anti-knock gasolines without the production of coke or tar.

The discovery of the prolific East Texas pool of high-gravity sweet crude will no doubt retard a widespread adoption of the hydrogenation process by the petroleum refining industry.

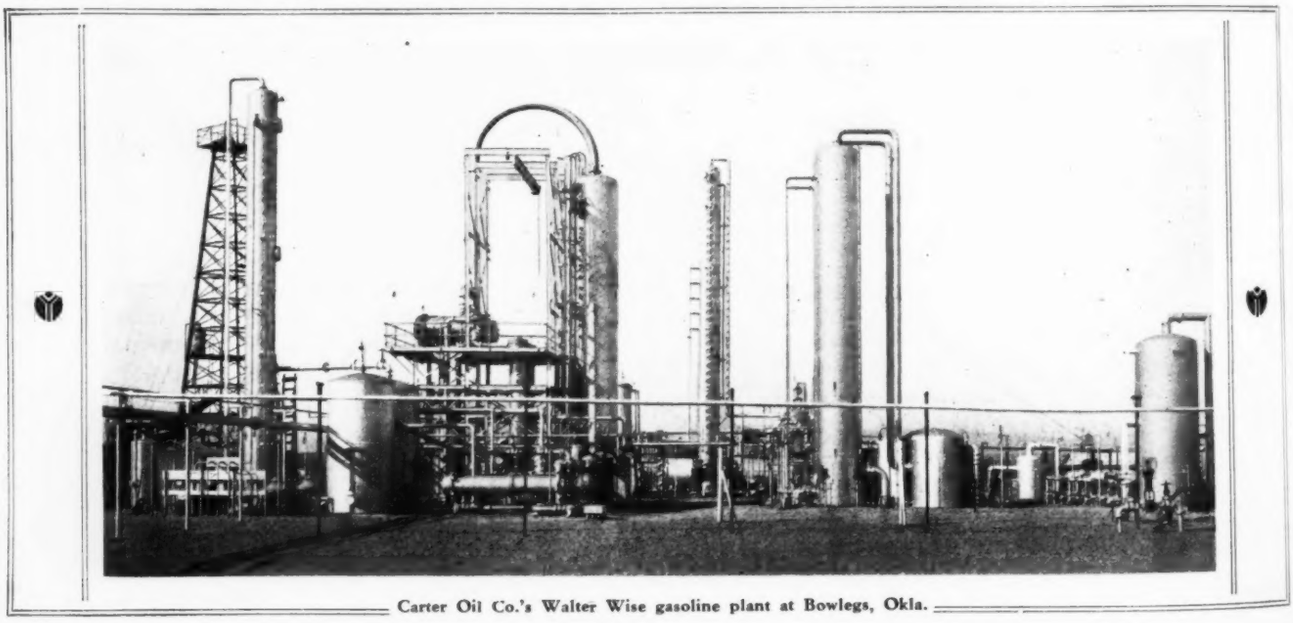
Refinery engineers have adopted many new methods in construction developed in recent years. Welding is extensively used in the refinery. Radius bends are more widely used. Electricity is now used to a greater extent than ever before for power purposes. Motor-driven centrifugal pumps are used for both light and heavy oils. Flood-lighting is used in most plants for night operation. Refinery engineers and chemists appear to be always on the alert to adopt or use new methods and equipment which will improve operations and reduce costs.

Through the medium of the many technical societies there has been great co-operation between the technical men employed in the refinery industry and those of other industries. Through this co-operation the refiner has been offered new materials for constructing better equipment and has been able to improve his motor fuels and lubricating oils to best meet the requirements of the modern automotive and aviation engine.

Much attention has been given to the manufacture of new products from petroleum hydrocarbons. Many chemists and research engineers are working on various processes for manufacturing alcohol, solvents and chemicals from petroleum. H. M. Smith, petroleum chemist with the U. S. Bureau of Mines described various methods of manufacturing chemical products by converting the hydrocarbons in natural gas. Three general methods were discussed: controlled oxidation—either with steam or by oxygen or air in the presence of suitable catalysts; pyrolysis—the breaking up and recombination of the gas molecules by means of heat; and chlorination—the replacement by chlorine of more or less hydrogen in the hydrocarbon molecules. Smith also described the manufacture of benzol for motor fuel from natural gas by pyrolysis. Preliminary figures show a yield of 0.3 gallons per 1000 cubic feet of methane.

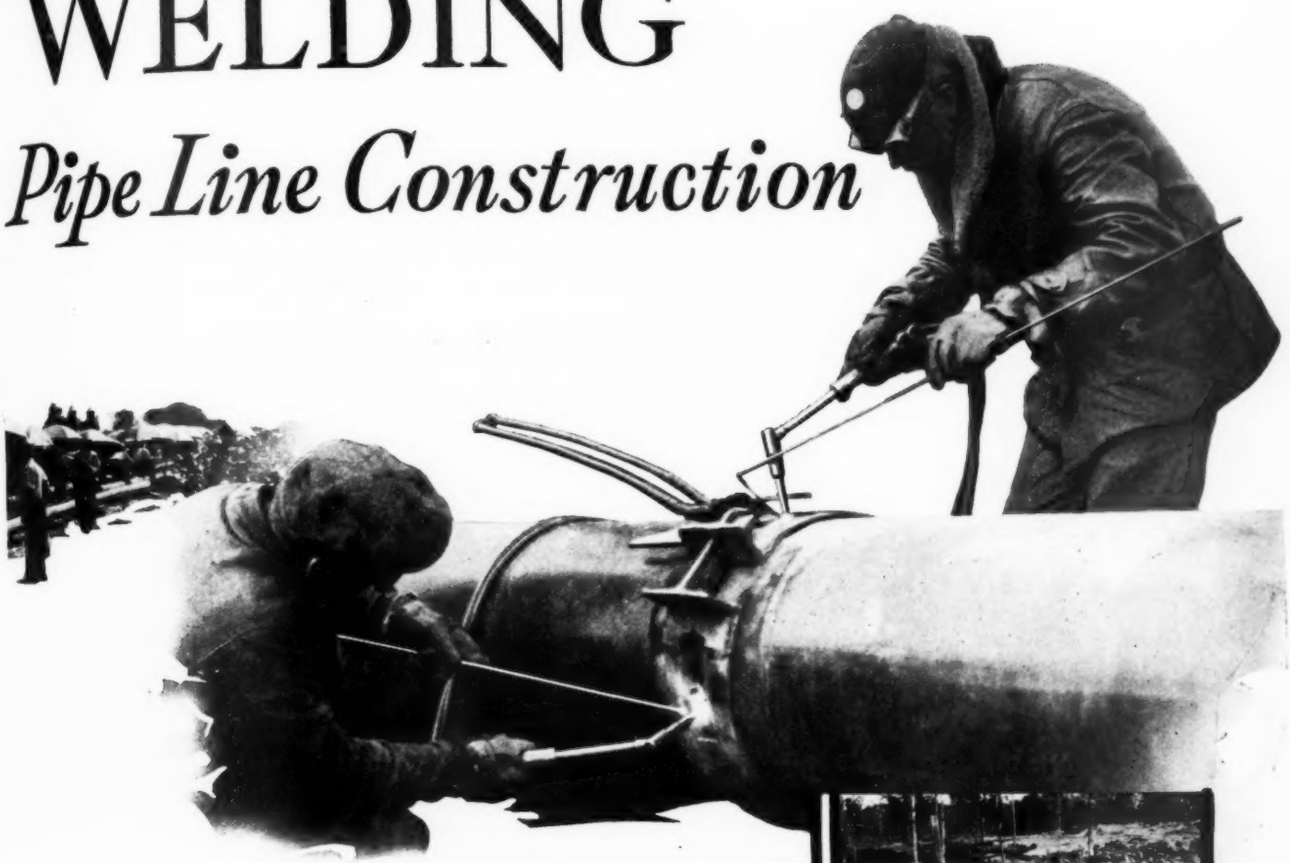
Chemists employed by the Standard Oil Co. (Ind.), have manufactured synthetic lubricants of superior quality by the polymerization of unsaturated wax distillates. These lubricants showed a low pour point, a low carbon residue, and possessed a flat viscosity-temperature curve. Actual tests on these lubricants showed that they had superior properties compared with those refined in the conventional manner from crude oil. During the past two years the carbon black industry was greatly expanded in Louisiana and Texas. Waste natural gas from which the gasoline had been extracted was utilized as a source of supply. Great overproduction of carbon black resulted. The construction of gas lines to carry this natural gas to the large industrial centers will, no doubt, reduce production of this product. A new process has been developed to manufacture carbon black from heavy asphaltic crude oil.

As the chemistry of the non-benzenoid hydrocarbons becomes better understood more products will no doubt be manufactured on a commercial scale, using natural gas and crude oil as the raw material.



Carter Oil Co.'s Walter Wise gasoline plant at Bowlegs, Okla.

WELDING
Pipe Line Construction



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A Novel Pump Station Manifold

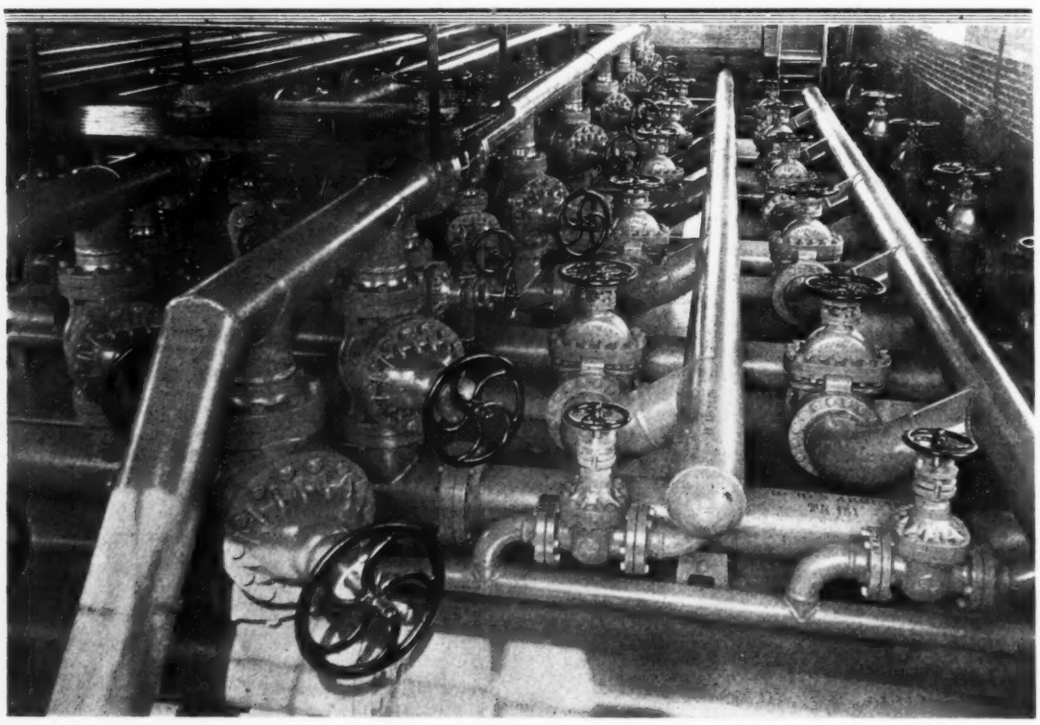
By R. W. SPARROWHAWK,
Oklahoma Pipe Line Co.

Risers and horizontally set gates.

LAST fall when it was necessary for the Oklahoma Pipe Line Co. to increase its station capacity at Glenn Pool, Okla., the station's manifold system had to be rebuilt to care for additional capacity and more flexibility. Originally, the station received oil through three 8-inch lines from the Drumright station, located 35 miles to the west. It delivered crude through three 8-inch lines to Council Hill station, 36 miles to the southeast. Last year the Ajax Pipe Line Co. completed a double 10-inch line extending from Glenn Pool station to Wood River, Ill. With these several lines through which various grades of crude would be pumped, it was necessary to design a manifold permitting great flexibility in operation. It is frequently necessary to pump one grade of crude south to Council Hill station while receiving another grade from that station. At the same time oil would be received from the station to the west while deliveries were made to the Ajax line running north.

To meet these conditions, the manifold shown in the isometric drawing was designed and built at a reasonable cost. The suction and discharge lines for each unit are laid parallel, reducing the crossing of these lines to a minimum. The manifold is simple in operation, free from reverse bends, built to normal ditch depth, with the lines and gates so spaced to afford freedom and accessibility for repairs or maintenance.

The suction line on the emergency unit is tied into each outgoing line. The station and manifold is belted with an 18-inch suction line tied into the two station tanks to insure the pumps filling when all units are in operation. With such a manifold it is possible to pump to and receive from the same direction at the same time; and pump to and receive from a different direction at the same time.



Looking down the manifold at Glenn Pool station.

By properly setting the gates one grade of crude oil may be pumped from Council Hill to Glenn Pool. At the same time another grade of oil may be pumped south from Glenn Pool to Council Hill. While these streams are being handled, oil may be received from Drumright station to the west while deliveries are being made to the Ajax lines.

The advantage of having the emergency unit line tied into each of the outgoing lines is, in the event of a break the crippled line may be sucked out with the emergency unit without interfering with any of the other lines.

By designing the

manifold so that all lines would be at normal ditch depth, a material saving was made in construction costs. The pit is only three feet deep, requiring less excavating and concrete work. At such a depth it also brought about a saving in piping and will hold maintenance cost at a low figure.

Paralleling the suction and discharge lines not only eliminates numerous and troublesome cross-overs, but saved considerable in pipe cost. Its greatest advantage probably lies in the fact the lines are easier to strip whenever necessary, because they are not crowded together and crossing each other. It is also easier to anchor the lines whenever desired. Where the units in a station are similar it is possible to lay these lines without any crossing whatever.

Ample room is provided for tightening flanges, packing, valves or any other work. The entire assembly has four-foot centers, thus preventing crowding or cramped corners in any section of the manifold. It also facilitates cleaning and makes possible a closer inspection.

Most of the gates on the risers have been set on a horizontal plane. This not only makes the opening or closing of the gates easier, because the gate wheels are located at a normal height, but it is expected to reduce sand cutting to a great degree. These gates are on the discharge lines from the units and by being on a horizontal plane there is less chance of sand (which ordinarily would collect near the seat) cutting the valve discs or seat rings. It is also insurance against foreign material collecting in the valve seats and preventing a complete shutoff.

The remainder of the gates have been flanged in vertically. Plug valves have been put in on the discharge barrels at the south end of the manifold. The check valves are just inside the manifold building on the discharge lines.

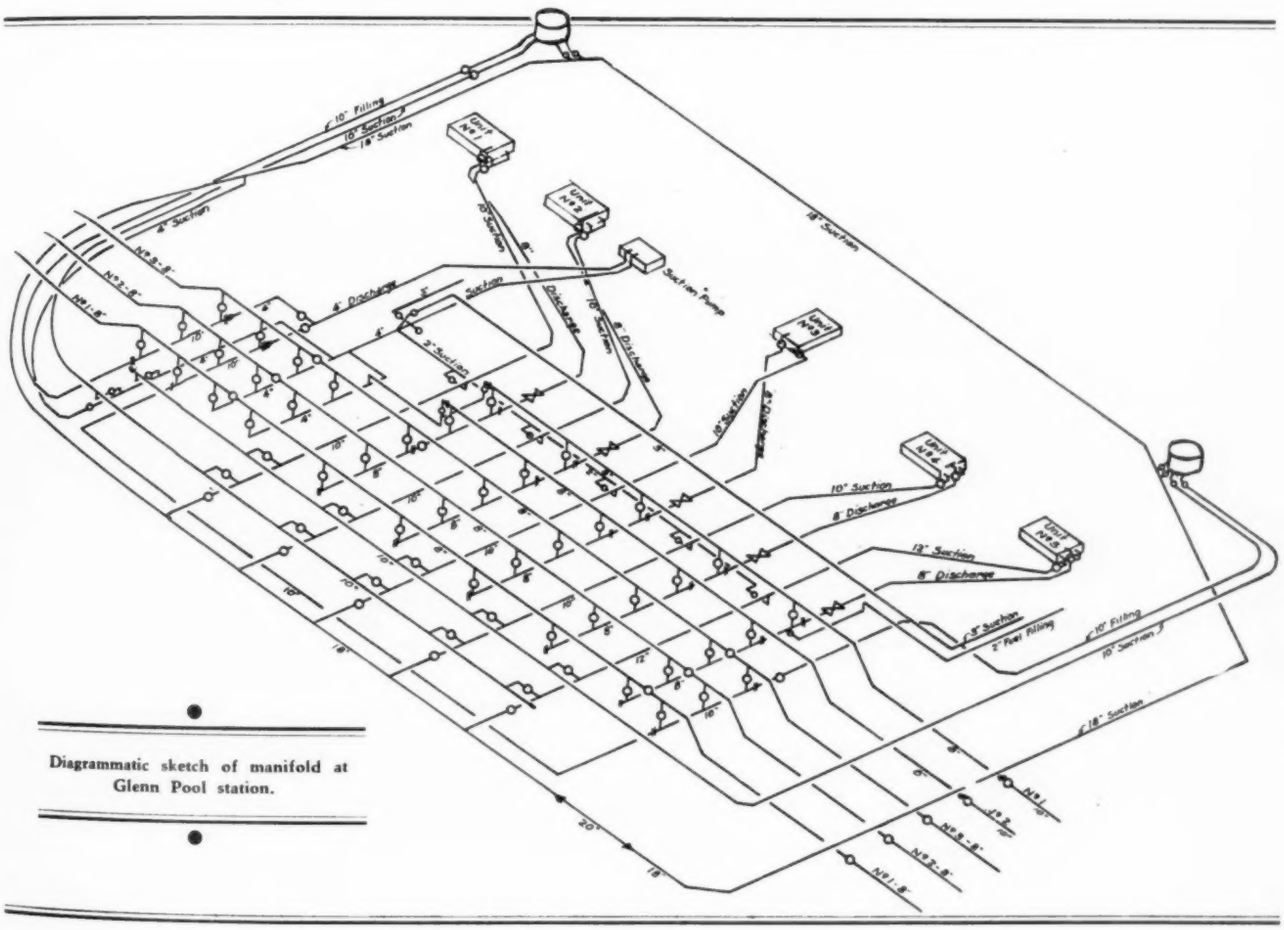
The station is surrounded by an 18-inch suction belt line. This line was built to prevent starving any one unit whenever several units were receiving their suction from this line.

In addition, each of the two working tanks is connected to the manifold by a 10-inch suction line, thus permitting the handling of two different grades of crude from station storage. These tanks are also tied into the manifold with a 10-inch filling line, which permits the receiving and delivering two different grades of oil at the same time in the same direction.

The suction and discharge barrels were measured and the openings in the pipe for the fittings were marked. A welder with a cutting torch made the cuts. When the manifold was ready for assembly the risers were tack welded in place and the flanges bolted together. At the same time the barrels were leveled as the flanges were tightened. This not only insured having the parts in alignment but in effect made a jig to prevent warping during welding.

The manifold is supported on the floor by cast iron pedestals, especially designed for the job. These are grouted into the concrete floor and make the assembly rigid. The pedestals are cast in halves, the top half designed to fit the curve of the pipe. A half bolt hole was made in the center of each half and as this is tightened it brings the pedestal rigidly against the bottom of the pipe it is supporting.

Each gate is numbered but the simplicity of design makes it easy for an operator familiar with the manifold to see which gates are to be opened or closed for varying conditions. The floor is painted a battleship gray as is the piping and valves. The gate wheels are all painted black and the walls from the water table up are painted gray to improve natural lighting.



Diagrammatic sketch of manifold at Glenn Pool station.

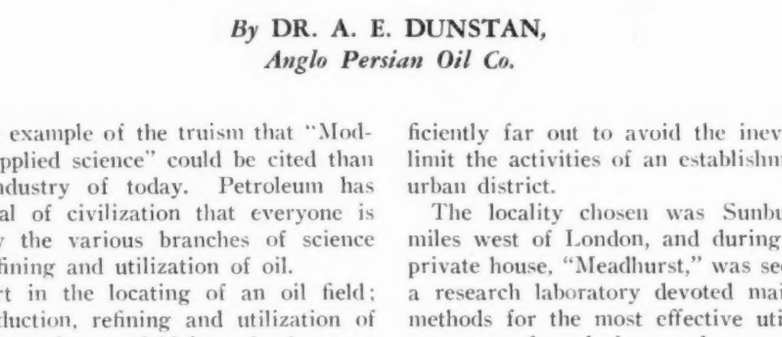
Chemical Research and Its Contributions to Refining Progress

By DR. A. E. DUNSTAN,
Anglo Persian Oil Co.

NO MORE striking example of the truism that "Modern industry is applied science" could be cited than the petroleum industry of today. Petroleum has become such an essential of civilization that everyone is now aware how closely the various branches of science bear on the winning, refining and utilization of oil.

Geology plays its part in the locating of an oil field; engineering, in the production, refining and utilization of the products; physics, entomology and biology, in the preparation of special derivatives; while chemistry finds constant application at every stage.

At a very early period in the development of the Anglo-Persian Oil Company, the directors realized that only by intensive research on the many problems, chemical, refining, engineering, geological and physical, which were involved, could their raw material be produced and converted with the fullest efficiency into products of the highest grade and maximum suitability for their specific purposes. The decision to establish a research station was taken in 1915, but, owing to the exigencies of the time, only a nucleus establishment was maintained until the war had ended. Nevertheless a large amount of extremely important research work on problems connected with the utilization of petroleum as a "munition of war" was done during this time in close collaboration with the Fighting and Munitions Services.



A test engine for lubricating oil research.

The selection of a suitable site for the research station demanded careful consideration. Proximity to the great refinery at Llandarcy, near Swansea, offered certain advantages in affording ready supplies of material and enabling close touch to be kept with the chemical and operating staff of the refinery. It was, however, realized to be essential that the research staff should be in the closest personal contact, not only with the nerve center of the company's organization at Britannic House, but also with the most recent developments of scientific thought and activity, the most eminent of scientific societies and the most complete and up-to-date of scientific and technical reference libraries. In these respects London leads the world, and it was therefore decided to establish the department near London, but sufficiently far out to avoid the inevitable restrictions which limit the activities of an establishment of this nature in an urban district.

The locality chosen was Sunbury-on-Thames, eighteen miles west of London, and during the war period a large private house, "Meadhurst," was secured and converted into a research laboratory devoted mainly to the discovery of methods for the most effective utilization of petroleum as a source of explosives and power.

By 1919 the value of the research department had become so thoroughly appreciated that a site of six acres adjacent to "Meadhurst" was acquired, and upon it has been gradually developed a research station that compares favorably in size, equipment and staff with other organizations of similar nature, and which has gained a reputation, both at home and abroad, not only for its main functions, but also for its contributions to pure scientific research.

It will be readily realized that the nature of the research work and other scientific investigations required by such a great organization as the Anglo-Persian Oil Company and its associates, must cover a very varied range. With this important aspect of the work in mind, the station was laid out as a group of separate buildings, each of which was designed and equipped for a specific type of work, ranging from pure chemical research on the individual chemical substances present in petroleum and pure physical research on the theory of lubrication, to the complete refining of crude oil on the one-ton scale, and the very detailed examination of the products in various types of internal combustion engines.

The chemical laboratories, with the library, drawing office and engineering shop, constitute the central block of buildings. Attached to the main laboratory are several smaller rooms which can be allocated for specific purposes, such as a dark room for photometric tests, and a "sunlight arc" room in which the chemical effects of sunlight can be simulated. In this laboratory new ideas, new materials and new processes can be tried out on the test-tube scale before translating them to the larger scale in the experimental refinery.

The analytical laboratory forms an important annex to the main laboratory. To this section comes a constant stream of samples of the crude oil from Persia, Iraq and other centers of production, and of petrols, kerosenes, fuel and Diesel oils, and lubricants, taken both at the refinery tanks and again at the distributing centers of the British Petroleum Company. In this way any variation from the normal standard of quality is at once detected and the cause traced. Specimens of oil, water, gas and mineral deposits sent home for examination by the company's geologists are also analyzed here.

In addition, careful analytical control and record is kept of the quality of such items as refining chemicals, water and water-softening components, building materials, steels and other alloys, paints, enamels and the hundred-and-one miscellaneous articles which are used by other departments of the company and by the various associated companies. An important phase of this work is the development of improved or new methods of analysis, and several analytical methods worked out in this laboratory have been subsequently adopted officially as British Standard Methods.

The library is, of course, an essential adjunct to a research department not only for its works of reference but also as a means of keeping in close touch with the most recent developments of the industry. All the important scientific and technical journals are available, and an effective system of abstracting and card-indexing adds greatly to the accessibility of information.

The engineering shop, which adjoins the chemical laboratories, is a well-equipped building with ample facilities for constructing and handling the various pieces of plant which are necessary for the larger scale investigations.

The experimental refinery is the largest building on the site, and it is possible here to translate the laboratory experiments, with ounces of material in glass apparatus to the hundredweight scale in steel plants, which is in turn a small-scale replica of the still larger units of the refineries.

This method of developing new industrial processes from the laboratory scale through intermediate stages before they ultimately reach the full scale of production, is generally accepted as the most efficient and most informative mode of progression, for it ensures the solution of the many inevitable difficulties, and gives the personnel the necessary experience and technique with the minimum of expenditure of material, money and time. With the knowledge acquired in the intermediate-scale plant the final full-scale units can be designed with far greater certainty of success, and meanwhile, a skilled operating staff can be trained.

One section of the experimental refinery—the still house—contains a number of oil-fired stills of graded capacity from one ton downwards. Some of these are designed for working under high vacuum and are therefore suitable for the distillation of lubricating oils.

Adjacent to the still house is a battery of washers which can be operated either continuously or discontinuously by suitable adjustment of the pipe and valve system. In these washers the necessary chemical treatment can be given to the unrefined distillates produced by the stills in order to eliminate those impurities which are deleterious to the finished products.

Beyond this washery is the lubricating oil and wax section, equipped with refrigerating plant and filter presses for the production of these important petroleum derivatives. A complete Edeleanu unit for the refining of oil by liquid sulphur dioxide is also erected in this section.

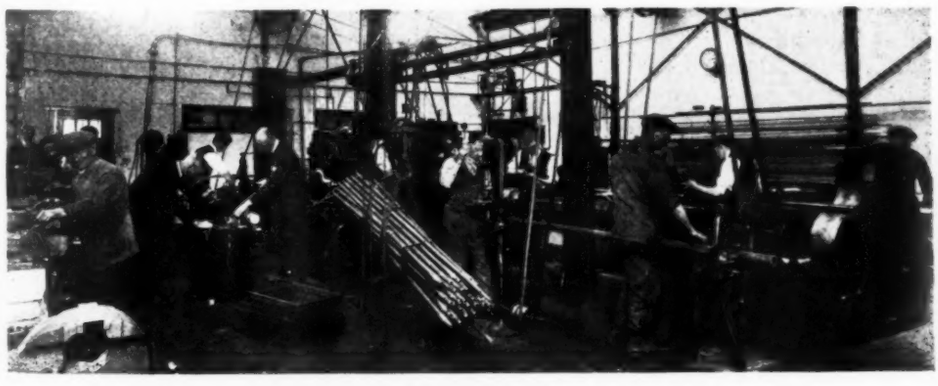
It is, therefore, possible, after a preliminary examination in the laboratory, to distill a relatively large quantity of any new crude oil and to prepare from it all the main derivatives, in a refined condition, on a scale which closely resembles refinery conditions and which is of greater guidance than a laboratory test alone could be.

The power house contains a 40-hp. Diesel engine which not only generates the electric power used by the research department, but which can be used for investigations on Diesel fuels and on lubricating oils. The switchboard is constructed in separate panels so that the power consumption of any unit of plant can be controlled and measured independently. An accumulator battery, a steam-driven dynamo and a motor-generator set provide alternative sources of electric power at convenient voltages.

The boiler house contains the oil-fired boilers which supply the stills and laboratory with steam. In this building is also the machinery for supplying vacuum and compressed air as general services.

The experimental house is suitably equipped for any type of chemical or engineering research which cannot conveniently be done in the other buildings. Research on natural gas and on the cracking of heavy oils is in progress in this building. It also houses a small-scale continuous high vacuum still which has served as the model for a large refinery unit. This still is of the pipe-heater and fractionating-column type, so designed that crude or fuel oil can be supplied continuously to the pipe-heater which is enclosed in a gas-fired furnace, while the fractionating column yields continuously a residuum pitch, and heavy, medium and light lubricating oils. By a complex system of pyrometers and electrically-heated windings each section of the column can be kept at a definite temperature, and very complete information can be obtained as to the necessary conditions for the production of any desired distillate. The whole unit can be operated at pressures down to one or two millimeters of mercury.

This section also contains experimental plant for the determination of data essential for the design of full-scale



Engineering work shop, Sunbury.

engineering units. Information as to specific and latent heats, heat transfer in pipes and fractionating columns, insulating materials, furnace design, pumps for special purposes, prevention of corrosion and similar refinery problems, is in constant request and involves research and apparatus of a highly specialized nature.

The Fuel Research Laboratory

Since the ultimate destiny of most petroleum products is to generate power by combustion, one of the most important sections of the department is concerned with testing the behavior of light and heavy fuels in explosion and in Diesel engines. A special laboratory has therefore been equipped with a wide range of engines of various types, each provided with the necessary instruments for recording and controlling its operation.

The laboratory is divided into three sections in which are housed research engines, commercial engines and Diesel engines respectively..

The first type are small single-cylinder units which have been designed at Sunbury in co-operation with Messrs. Armstrong-Whitworth, and are used principally for researches on motor fuels.

They are fitted with variable compression cylinder heads, adjustable controls for speed, load, fuel, air supply and operating temperature, with automatic detonation and acceleration recorders, and even with transparent silica windows in the cylinder so that the flame of the explosion can be photographed. They thus represent the very latest development in the design of engines for research purposes. These engines can also be used for routine tests of spirits and their sensitivity is such that any change in fuel quality can be immediately detected.

Replicas of these engines, previously calibrated against the standard engine, have been erected at the company's various refineries so that each refinery can manufacture a petrol of identical anti-knock rating.

For special work certain of these engines are modified in detail. One, used for special racing fuels, can be used at compression ratios up to 14 to 1. Another, used for examining aircraft fuels, is jacketed with ethylene glycol so that it can be operated at temperatures common to air-cooled engines.

While engines specially designed for test purposes are essential for the true determination of certain important features of quality in engine fuels, it is also necessary to keep continually in touch with developments in engine design which may affect the fuel situation. The fuel research laboratory is therefore equipped with several modern types of multi-cylinder car and lorry engines and with the auxiliary equipment necessary for carrying out long period tests in connection with fuels and lubricating oils. Measurements can be taken to determine engine friction under any conditions of working, and also to compare ease of starting and acceleration and to co-ordinate these with the spirits under test and with the carburetion and distribution systems employed.

The Diesel engine section contains a variety of Diesel engines including the cold starting solid injection type, the hot bulb type and two-cycle and four-cycle high-speed engines. Special auxiliary equipment such as centrifuges for cleaning fuel, high pressure chambers for testing sprayer action and Farnboro indicators for taking indicator cards is also installed.

The chemical laboratory included in the research station is available for the analysis of fuels and lubricating oils and contains the most up-to-date equipment necessary for their physical and chemical examination.

The facilities provided for dealing with problems of fuel quality and its relation to engine design has proved to be a means of helping to establish a close co-operation between the engine designer and fuel producer. The engine designers have here a means of obtaining first-hand knowledge of matters relating to fuel and, just as the fuel producers profit by the study of development in engine design, so also the engine designers cannot fail to derive benefit by a closer knowledge of fuel problems and of the methods employed by the producers to test the quality of their product under actual engine conditions.

In addition to its functions as a research station for the purposes previously outlined, as an analytical laboratory, and as a source of information on all scientific matters which come within the company's purview, this center plays an important part in the training of the company's chemical and chemical engineering staff. The closest contact is maintained between the research station and the chemical laboratories at the Persian and Iraq oil fields and the various refineries.

Sometimes a problem must be investigated at the oil field and, therefore, an "extension" of Sunbury has been installed at Masjid-i-Sulaiman working in close collaboration with the main research station and staffed by chemists who have been members of the Sunbury staff.

Members of the research staff frequently visit the company's refineries and fields in connection with specific problems, while chemists from the other centers are at regular intervals attached to Sunbury for a period. Furthermore, chemical recruits generally spend several months in training at Sunbury before passing out to the refineries or the oil fields.

This system results in a continuous exchange of ideas and viewpoints and a personal acquaintance with colleagues, which add greatly to the esprit de corps and efficiency of the company's chemical service.

In addition, a general chemical conference, attended by representatives from every center of the company's activities, is held each year, at which the current and future programs of development and research are discussed.

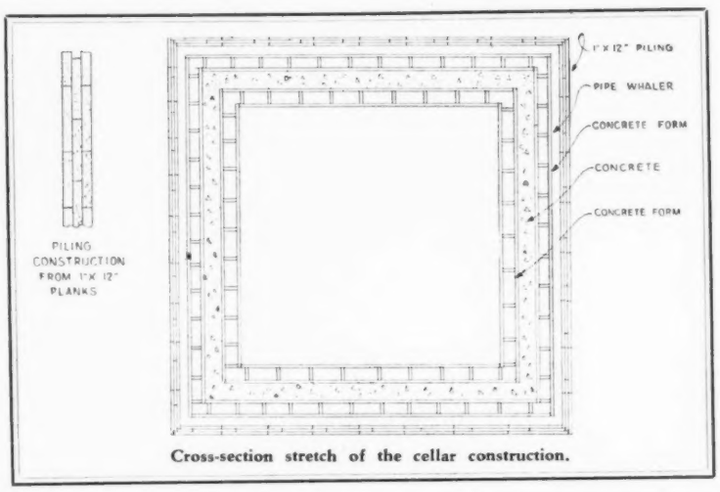
Although the activities of the research department are naturally mainly directed to the particular service of the company, a considerable amount of valuable fundamental research is also carried out, the results of which are published as a contribution to the world's scientific knowledge. Furthermore, the senior members of the staff are associated with the activities of scientific committees of various Government departments and in this way are able to apply their knowledge and experience for general benefit.

When writing E. H. EDWARDS COMPANY, *please mention The Petroleum Engineer*

IMPROVED Rig Cellar *and* .. Foundation Construction Job

OIL field rig cellars entirely clear of obstructions and river-bed rig foundations completed at considerable savings are the features of several very interesting construction jobs recently completed by the Indian Territory Illuminating Oil Company.

The company has succeeded in building a cellar that is free of timber bracing for sill support, thus eliminating a fire hazard, and leaving the cellar free from obstructive material, which gives workmen more room for performing cellar duties and lessens the danger of an injury. This is a very important development especially in high-pressure areas, where large, elaborate systems of control gates are necessarily installed, and where wild wells and fire are more likely.



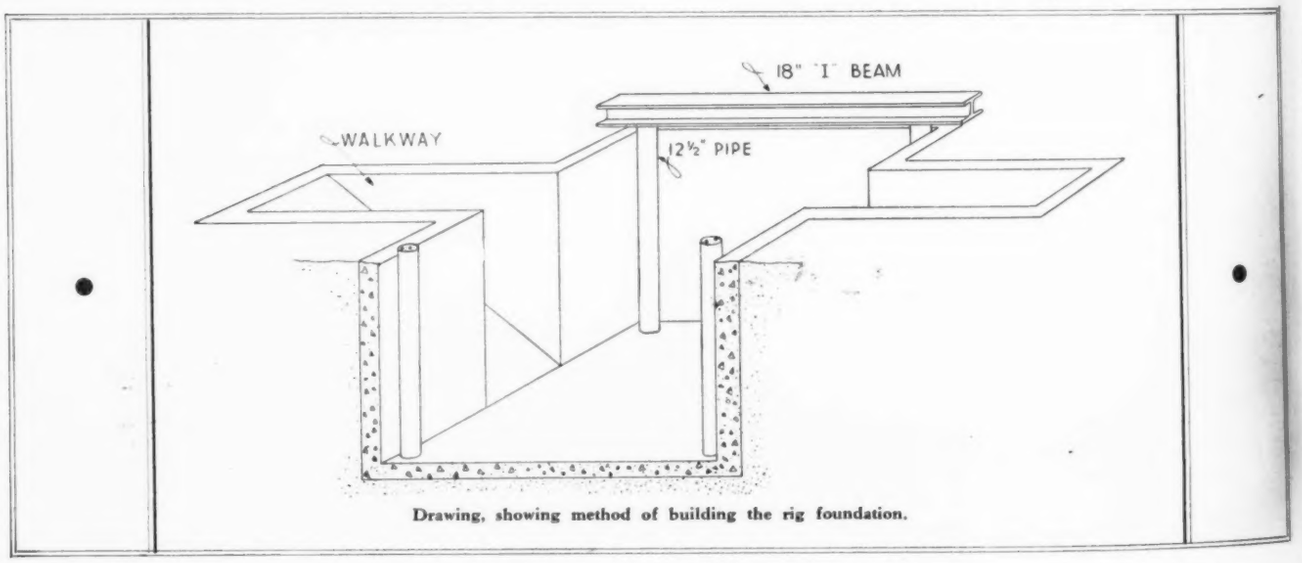
Cross-section stretch of the cellar construction.

In each corner of the cellar a 12½-inch diameter pipe has been driven about 35 or 40 feet into the ground. The formation, naturally collected in driving the pipe, has been drilled out and the pipe filled with concrete. Across the top of these pipes 18-inch I-beams have been set to support the crown sill of the rig. This method of construction has left the entire center of the cellar free from the usual large pieces of timbers. The entire cellar, including walls, floor and walkways is built of concrete.

Construction of oil field rig foundations in areas that do not have solid surface formations is difficult and usually expensive. This has been true in the district abutting the quick-sand banks of the Canadian River in the north end of the Oklahoma City field. The Indian Territory's new rig foundations in this district have been constructed by a different method from the general practice. A considerable cost expenditure has been saved by the company because of reduced erection cost and salvaging. The general practice in building rig foundations in the area has been to build large wooden boxes and lower these into the excavation as piling to withhold the cavey formation.

Salvability of material used has been secured by the I. T. I. O. Co. by bolting the pilings and concrete forms. After they have been salvaged from one location, the company can use them in building other similar foundations. This plan of rig foundation construction was first used on the company's M. K. T. lease B well No. 1, and since has been used at several other drilling sites. The work has been under the supervision of Paul Walleck, head of the construction department.

The piling necessary to keep the sand from caving in has been made from 1x12-inch planks. Three of these planks are overlapped, giving the piling a thickness of three inches. The ends of the planks are so placed that they are not at the same point, greatly strengthening the piling. The piling has been driven into the ground about 20 feet, or until a solid formation is encountered. Pneumatic tools have been used to drive the piling. A pipe whaler was set on the inner side of the piling. After excavating the dirt from the center of the enclosure formed by the piling, concrete forms were set and the concrete poured. As soon as the concrete hardened the company salvaged the material it could and started construction of the derrick.



Drawing, showing method of building the rig foundation.

Verticals with Brawn

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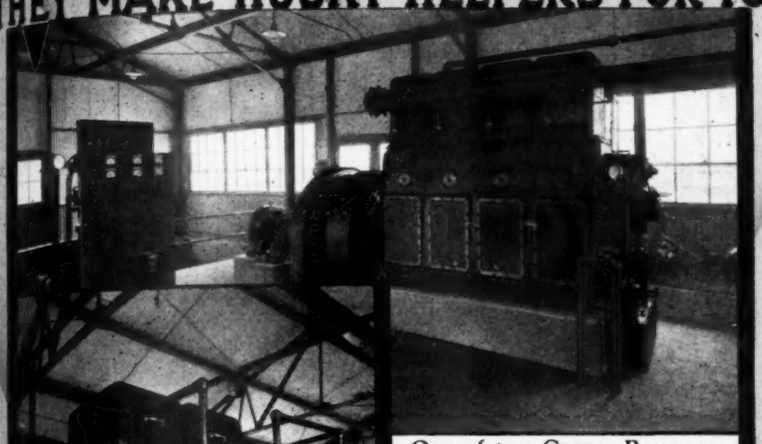

One of two Cooper-Bessemer 200 B. H. P. Vertical gas engines direct-driving 156 K. V. A. generators in Sterlington station of United Gas Company. Kline Spur, La.

Cooper-Bessemer 90 B. H. P. Vertical gas engine direct-driving 75 K. V. A. generator in Cole Bruni station of United Gas Company at Bruni, Texas.

A large-diameter die-forged crankshaft is just ONE of the strong points of the 11½x14" convertible vertical engine. Every part subject to heat, friction, stress and strain is heavily fortified against trouble. It is wise to choose auxiliary power units with the same care you do main compressor units. Thoroughly investigate these compact, enclosed vertical engines for dependable compressor station service.

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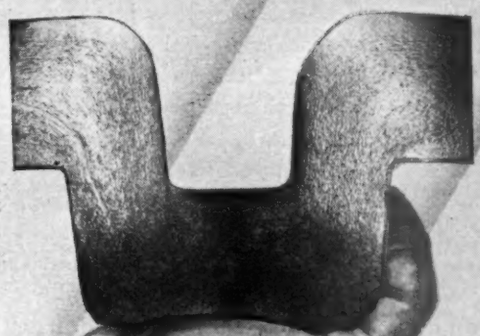


Like the sinews of a mighty arm, the fiber in this die-forged crankshaft is directed to resist stresses. Cross-section photo shows continuous flow lines.

COOPER-BESSEMER

. . . Progress in . . .

STANDARD CABLE TOOL DRILLING PRACTICE

STANDARD cable tool equipment has been vastly improved in recent years. Drilling a hole today with cable tools to 7000 feet is accomplished with as little difficulty as a 2000-foot hole was a decade ago.

Much of this improvement is attributed to the co-operative work done by A. P. I. standardization committees and manufacturers. Steel derricks of ample strength for drilling to 10,000 feet are available. Rig irons are constructed sturdy enough to meet the rigid requirements that deep drilling demands. Modern cable tool drilling operations have been speeded up by the use of sand reels of improved design. Those of the more modern type are mounted on roller bearings, have a chain drive and are equipped with efficient brakes and clutches.

Crown blocks are fitted with accurately machined steel sheaves mounted on roller bearings. Improved lubrication systems for crown pulleys have eliminated much wear and consequent misalignment. This latter factor, coupled with the better grade material and more accurate machining of sheave grooves, has lengthened the life of drilling lines.

Steel drilling lines have been improved and the material and construction have kept pace with the increased demands of deep drilling.

Another item of surface equipment that has been designed to meet heavy drilling conditions and has contributed much to efficient cable tool drilling operations is the steel rig front. These stand up under heavy loads with a minimum of rig maintenance.

Notable progress has been made in drilling tools. Metallurgical study of alloy steels to meet the field requirements has gone on apace. The drilling bits of today used in deep holes are of materials that will stand up under the most severe drilling conditions and give greater footage than was ever thought possible a few years ago.

Cable tool coring bits have been improved in design to the point that good cores are obtainable in almost any type of formation encountered. This has been one of the most valuable adjuncts of cable tools that has been developed. In the Bradford field, Pennsylvania, their use has become general in coring operations, the latter being standard practice in connection with development operations for water flooding.

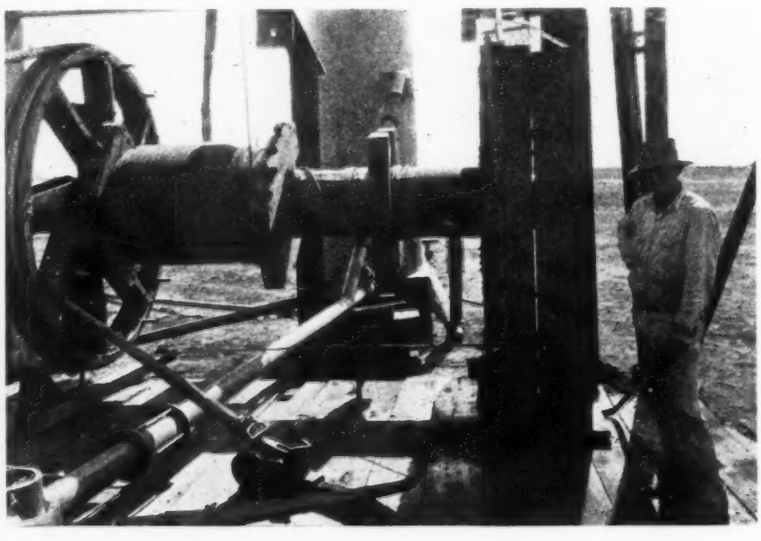
Engines for cable tool drilling are more rugged in design and have wider ranges of speed, hence have greater flexibility to meet the more exacting duties required in modern-day drilling operations. Internal combustion engines of the horizontal type are now available in speeds up to 450 r. p. m. It is through refinement in design, efficient lubrication systems, anti-friction bearings, the use of the best materials available and the reliability of this type of prime mover that has given it a place of increasing importance in standard cable tool drilling practice.

With the opening up of deep gas production in the New York-Pennsylvania region near Corning, New York, impetus has been given to the further adoption of modern standard cable tool practice.

In this field the hard, cavernous limestone rock encountered at respectable depths makes the standard cable tool system especially desirable. Also in the Western Kansas, notably around McPherson, modern standard cable tool methods are employed to advantage.

Many deep tests with rings equipped to go to 10,000 feet if necessary are drilling in different parts of the country.

These facts indicate that standard cable tool drilling practice has kept abreast of the times and still has an essential place in oil field development.



Cable tools cleaning out a Wilcox sand well in the Seminole, Okla., field.

Progress of . . . Slush Pump Pressure Measurements

By E. L. DECKER[1]

IN developing data for the study of the effect of slush circulation on drilling progress and circulation equipment we come face to face with the problem of measuring slush pump pressures.

Pressure gauges were installed on some of the first slush pumps ever to be used in connection with drilling water and oil wells by the rotary system. The type of pump used for drilling has been used for other purposes and had been equipped with gauges to indicate the pressure at which they were operating. It was only natural then that the first rotary slush pumps should have been equipped with pump gauges. The early operator soon found that it was a different problem to measure the pressure in pumps handling mud fluid than it had been under other conditions. The small pumps then in use had to be operated at very high speeds which set up such violent pressure pulsations that a gauge was soon rendered useless. The manner in setting up the pumps in those and subsequent days provided no method of tying them down so that the mechanical vibration was almost as bad. The last, and perhaps the greatest difficulty in measuring the pressure in those pumps, and the same problem exists today, is that of keeping the mud and sand out of the gauge. Once mud enters the gauge it becomes hard, not only rendering the gauge useless for the job, but entirely ruining the pressure element. New devices have been developed which overcome these difficulties and perfect indications and records of pump pressures can be obtained.

The antiquity of slush pump gauges is mentioned with some authority and is illustrated with a photograph from Frosty Martin's collection of old-time oil field scenes, Fig. 1. On the manifold of the pump is a 200-pound pressure gauge. This rig was set up in the spring of 1900—now 31 years ago. The two pumps were Smithvales, size 10-6-10, slightly larger than the present day boiler-feed pump. Perhaps the circulating system of that rig was more modern than the balance of the equipment. It will be noticed that the casing line is Manila. The rotary table weighed the staggering sum of 650 pounds.

Casing lines and rotary tables have no bearing on the measurement of slush pump pressures, but serve to illustrate that even in the earliest days of rotary, operators had the idea of measuring the pressures which their pumps were putting up. Certainly these little fellows could not put up very much pressure, but it was enough to cause the designer of the rig to want to know at just what pressure they were operating.

The gauge shown in this installation, as well as gauges used on other installations before and after this, did not stand up long. It is for this reason that slush pumps have been operated for years without pressure gauges. Without the aid of gauges little information has been compiled and very little study has been given the effects of pressure and circulation on drilling. There are few cases in modern industry where pumps of any kind have been operated at such pressures as those encountered in rotary drilling where gauges have been used so sparingly.

With deeper drilling, larger and stronger pumps became necessary. In sections where much of the hole was made with rock bits it was found that large amounts of fluid were required to keep the cutters clean and faster progress resulted. Naturally then, greater volumes result in higher normal operating pressures, and that trend has continued upward until today we have pumps that are tested to withstand pressures up to 6,000 pounds per square inch, in sizes up to 16x8x24. In some sections an operator whose pumps have a stroke of less than 20 inches and are operated with less than 300 pounds steam pressure is a back number. Such pumps put out tre-

Figure 1. This picture of a rotary rig was taken 31 years ago at Angleton, Texas. Notice the pressure gauge on the pump manifold, Manila casing line, small rotary table, etc.

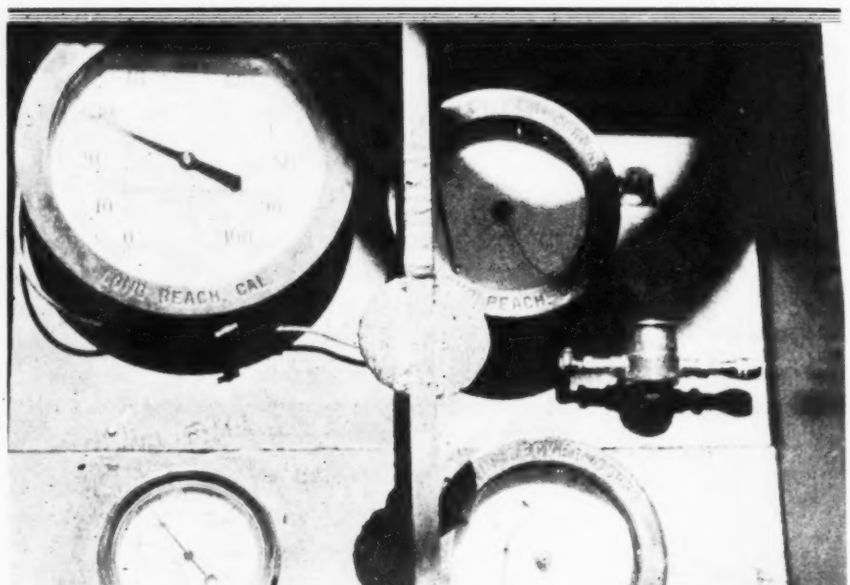
[1] Martin-Decker Corp.

mendous amounts of fluid and in most cases at pressures that would have run the old-time roughnecks and drillers off the rig floor had they known the actual pressure.

The pump accessories and fittings used in the hook-ups of yesterday certainly would not stand the pressures of today. In the Oklahoma City field, for example, we have found the normal operating pressure of slush pumps when circulating through 6-inch drill pipe to be between 600 and 750 pounds; when 4-inch drill stem is used the pressures run up between 1,050 and 1,200 pounds; when on 3-inch between 1,300 and 1,500 pounds, and under conditions of caving holes or plugged bits we may expect most any pressure.

We refer particularly to one case where the pressure amounted to nearly 1,500 pounds on a 6-inch drill pipe job before it was decided to pull out with the plugged bit and attending wet job. We have recently witnessed attempts to regain circulation where the capacity of a 3,000-pound pressure gauge was insufficient.

During the Santa Fe Springs deep drilling program normal pressures ran up to approximately 1,000 pounds with 2½-inch and 3-inch drill pipe. Little pressure information was obtainable there, however, as there were but few rigs equipped with pump gauges and none, to our knowledge, with recorders. Normal pressures at Beldridge and Kettleman Hills do not ordinarily approach those at Oklahoma City, but certainly there are many times where extremely high ranges must be put up to overcome the many difficulties encountered there.



Some of the gauges used on a modern rotary rig. Top—Weight indicator and recorder. Bottom—Pump gauge and recorder in the Oklahoma City field.

Having witnessed the result of one pump failure at high pressure which was at the cost of one life and permanent injury to another person, we feel that the safety factor alone would require a reliable gauge to keep the crew in constant touch with pump operations.

Frequent failures of pumps, pipe valves and fittings, and rotary hose have caused the development and use of much heavier and stronger material for all such parts. Forged steel, bronze and cast steel alloys of greater strength have, to a large extent, replaced cast iron and ordinary cast steel in pump valves, gates and stop-cocks. Rotary hose built up of rubber and inter-bedded with many layers of fabric and steel wire, and flexible steel rotary hose, withstand pressures today that the old-time hose could not hold. Sturdier hose clamps, high-pressure pipe and pipe fittings, and special pump pistons, all assist in controlling today's pressures.

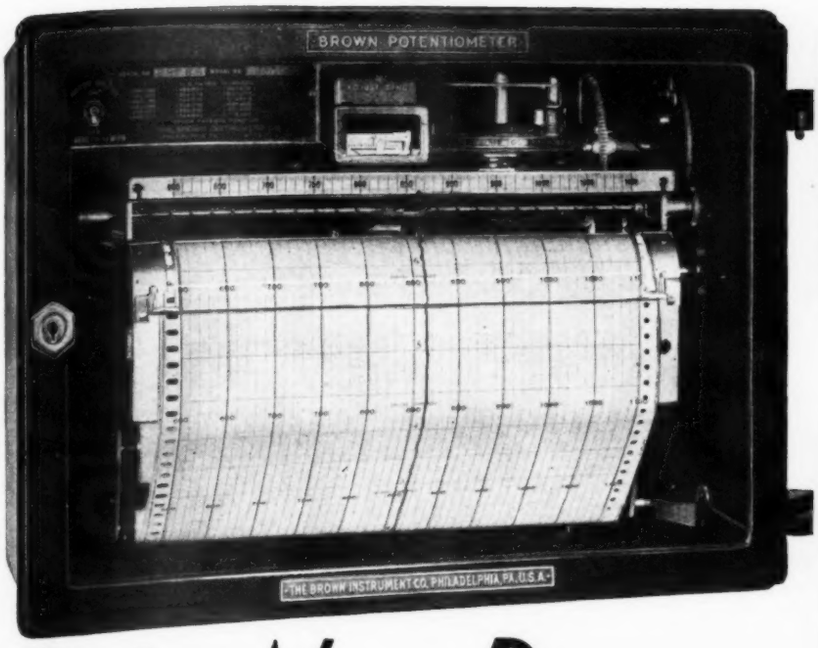
Drillers for years have depended upon the exhaust of the pump as an indication of pump operation. While this noise was nerve-racking to the bystander, it produced rhythm for the driller and was often the tempo to which he hummed or sang his songs, unconsciously analyzing from this rhythm circulating conditions. A slowing down of the pump in a certain manner meant the balling up of his bit with sticky formation, and another slowing up process meant lowering of steam pressure; an irregular sound replacing the usual rhythm meant an air leak in the suction or gassy formations or a pump valve that had gone bad. A sudden increase in the speed indicated a twist-off, a blown out connection, a gasket, etc.

With the increasing use of internal combustion engines and electric motors as prime movers for pumps, driving through various types of belts and gears, the driller has been robbed of the old familiar bark of the steam exhaust and so, therefore, is left more or less in the dark as to the conditions under which his pump is operating. This is also true, even with steam pumps in a great many localities, as it is becoming more and more the practice to install the pumps by themselves in a special pump house, which is usually set some distance from the rig. In Kettleman Hills, where most locations are made on hillsides, the pumps are located considerably below the derrick floor and with the rig housed in and the constant noise of the rotary, it is impossible to get an idea of pump action from the exhaust.

The driller then should, by all means, have a good reliable pump pressure gauge in front of him. He will be guided to a great extent in drilling by this gauge. Pump conditions not otherwise known to him will always be visible. Bad pump valves, worn piston rubbers and liners are seen through the gauge. Leaky lines, fittings and gaskets are shown on the gauge, even though the pump is located at considerable distance from the rig. No question can be raised about a twist-off as it will be shown instantly at the pump gauge. Plugged bits also show up right now and the gauge may be the means of knocking out the plug without blowing up a hose, as so often happens.

Cut-out tool joints, which are frequent with the high pressures of today, are visible through the pump gauge. We recall from a recent experience the installation of a slush pump gauge unit on a well in Oklahoma City. The unit was installed at the base of the standpipe on the derrick floor. Fluid was carried from the pumps to this point in the circulation system through about 25 feet of 3-inch pipe in which was fitted 12 ells and tees, making twelve right-angle turns. Another gauge and unit were installed at the pump itself. Comparison of the pressures at the two points disclosed a pressure drop of over 150 pounds in this short distance. The circulating pressure was 650 pounds at the standpipe. The result of this test makes plain to the practical man the advisability of eliminating angles as

Announcing



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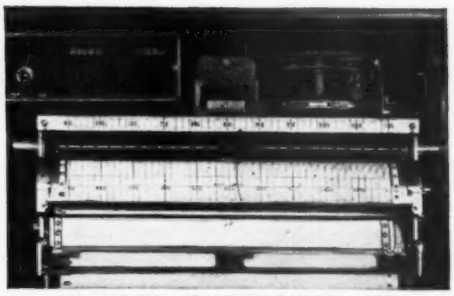

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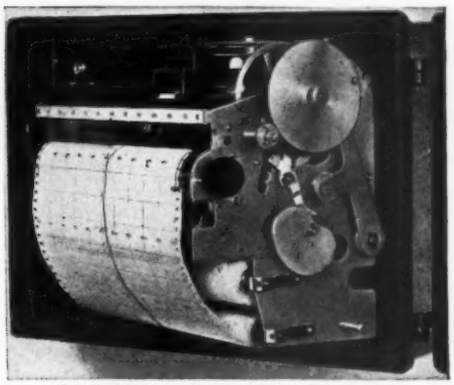

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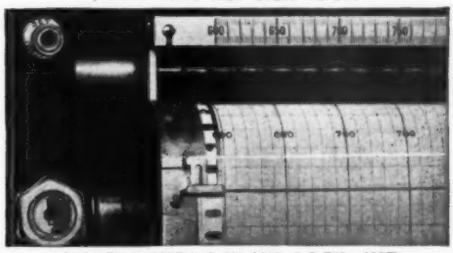

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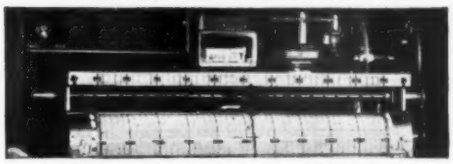

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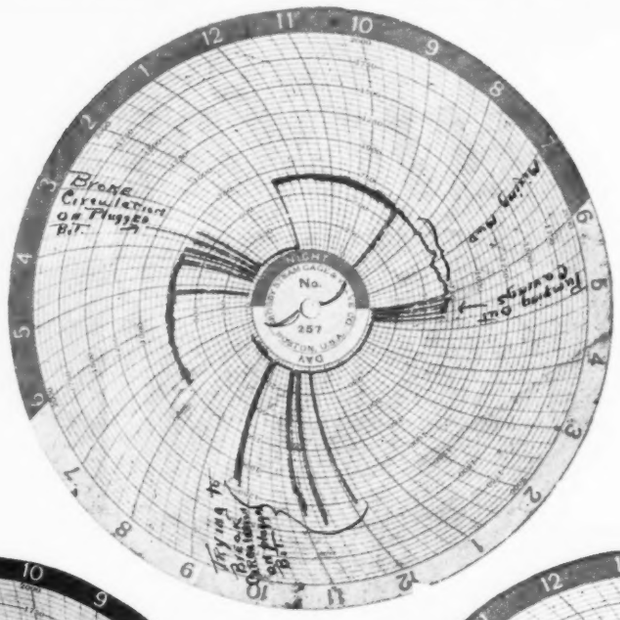
much as possible, permitting more efficient pump operation.

It has only been in recent years that the drilling departments saw any benefits in charts. True, the value of charts was not realized; further no instruments had been developed which would make a record of rig operations. Since the advent of the weight indicator many concerns are taking records on everything possible. Therefore, with a reliable pump gauge, gauge protector, and pulsation dampener, these concerns are naturally taking records of pump pressures. These charts permit the study of circulating conditions.

Life of pump parts, rotary hose, etc., is a matter of record with the charts at hand. Coupled with a stroke counter, the exact work done is shown. Failures of equipment can be checked, showing at what pressure it failed, and the time of failure.



Left—Figure 2. Settling of shale cuttings here caused a plugged bit. The plug was knocked out at 3:30 a. m. 9:45 a. m. to 12 shows 1450 pounds was used to break circulation on another plugged bit. This time a wet job was pulled.

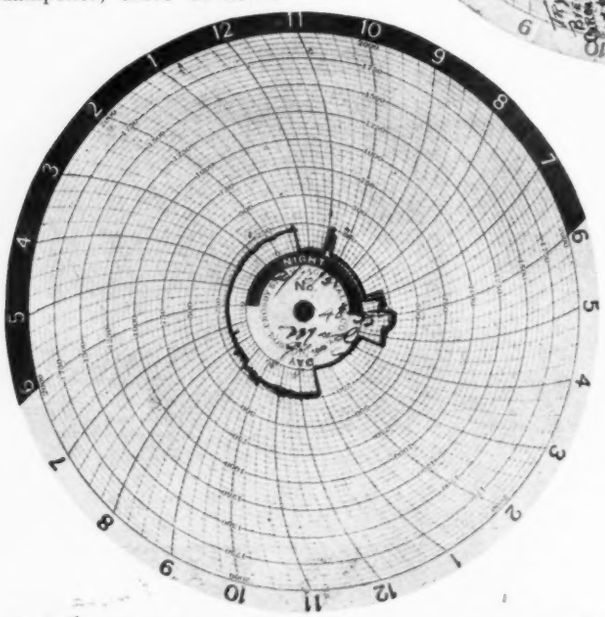


Figure 3. At 6:00 p. m. a 100-pound pressure drop occurred. This clearly illustrates what effect a twist-off will have on a pump gauge

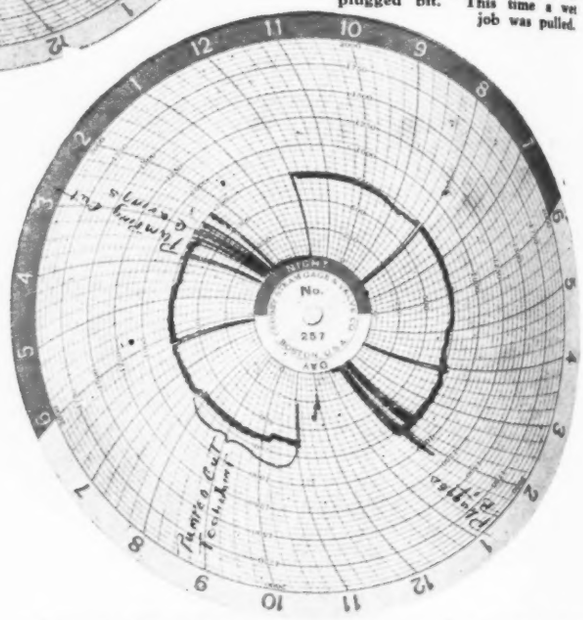


Figure 5. The gradual pressure drop from 7:45 a. m. to 11 a. m. caused the driller to look for trouble. Two cut out tool joints shown in Figure 4 were the result.

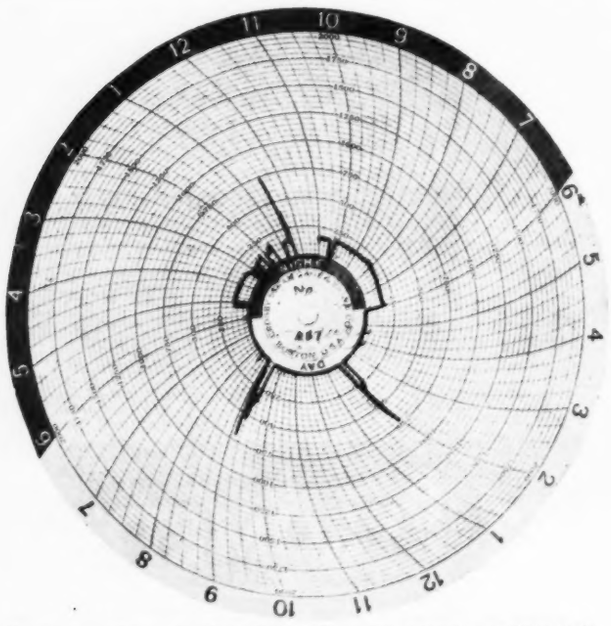


Figure 7. Shows at what time a "pressure tripped" straight hole device was run, also tells the driller when it had operated.

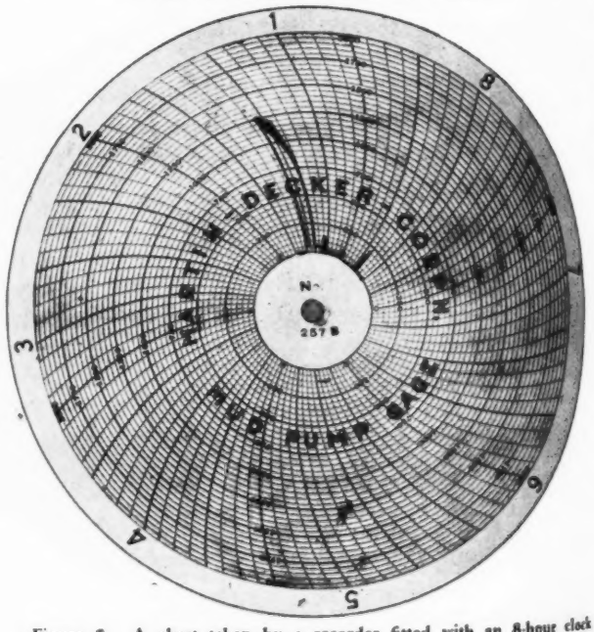
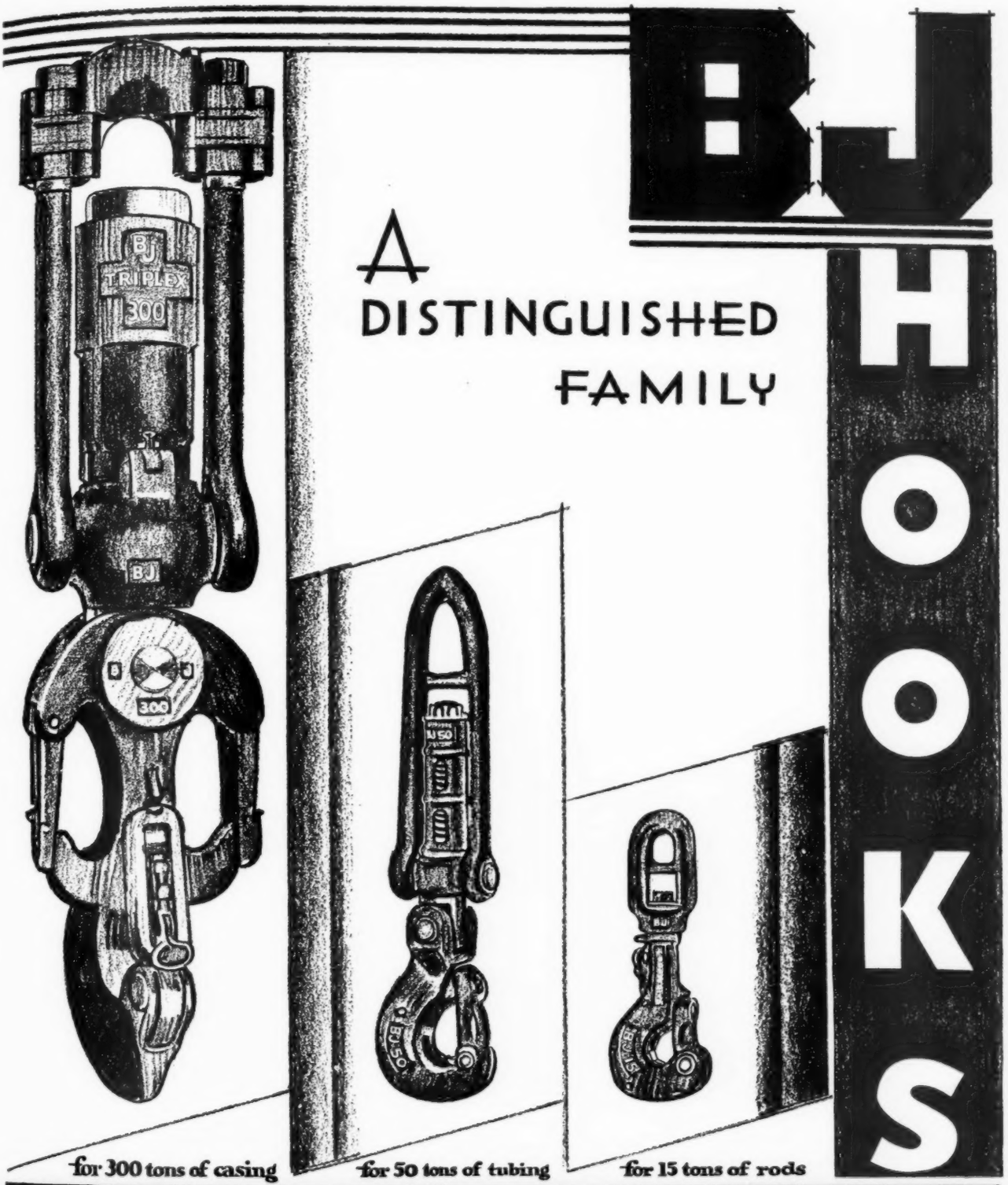


Figure 8. A chart taken by a recorder fitted with an 8-hour clock on a "squeeze" cement job.



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A NATURAL GASOLINE SURVEY of East Texas

By **F. M. NEELY,** *General Supt., Crosbie and Moran, Inc.*

IN ORDER to determine the feasibility of locating a natural gasoline plant in the East Texas field, a survey was made recently by the writer to determine the gas conditions existing there. Tests were made on wells within a three-mi'e radius of Kilgore.

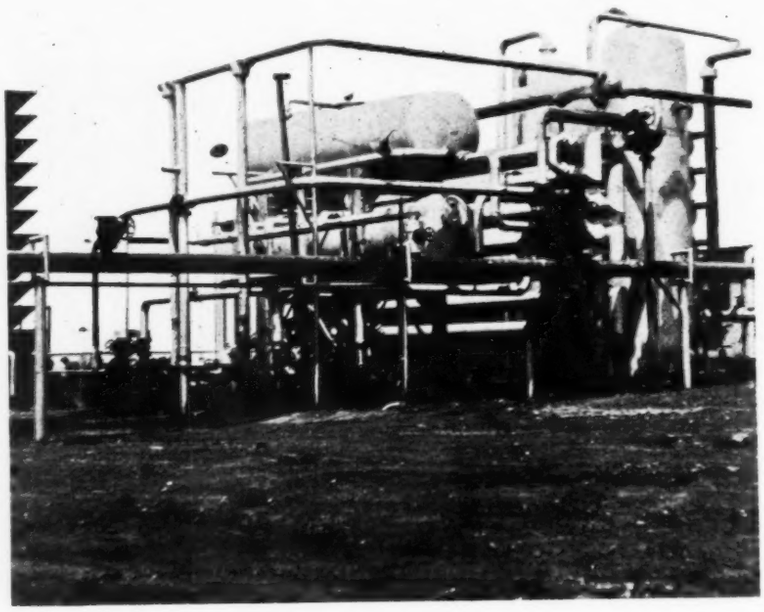
The results of some of these tests are shown below. They are representative of the whole area surveyed.

The gasoline recovered at 60 degrees F. from the first test had an 88.5 A. P. I. gravity and showed a 52 per cent weathering loss, indicating a high propane and butane content. A conservative estimate indicates about 275 cubic feet of gas per barrel of oil in this area. Many wells were shut in at the time the test was made. The wells farther north showed a higher pressure.

The oil comes out of the we'l at a temperature between 120 and 135 degrees F., consequently the vapors from the receiving tanks are very rich in gasoline and copious in volume. A test on one of the tanks showed a gross content of 6.80 gal. per M., and a net of 4.50 gal. per M. The high temperature of the oil is indicative of salt water; however, some producers claim that it is due to the friction from flowing through a 2½-inch tubing.

The survey indicates that there is about 50,000,000 cubic feet of gas per day available in the area surveyed. The average net gasoline content is 2.5 gal. per M. cu. ft. The gas is sweet and the gasoline would not require chemical treatment.

The conditions for building a gasoline plant are very satisfactory. The wells are close together. Railroad facilities are available for shipping the gasoline. Water is plentiful. Some of the disadvantages are that there is no native rock in the area, and, due to the large number of operators, metering equipment would be somewhat costly. The reasons, however, that no gasoline plants have been constructed in this field are entirely economic. The present low prices for natural gasoline would not justify an investment for a plant. Proration in the field may prove to be an added hindrance, since the flow of the wells would be very irregular, thus making plant operations difficult.



Tulsa-type equipment—distillation unit, Crosbie & Moran, Konawa plant.

First Test

Trap pressure	30 lb. per sq.in.
Well pressure	180 lb. per sq in.
Gasoline content, gross	4.80 gal. per M.
Gasoline content, net	2.30 gal. per M.
Volume of gas	900,000 cu. ft. per da.

Second Test

Trap pressure	30 lb. per sq in.
Well pressure	300 lb. per sq. in.
Gasoline content, gross	3.20 gal. per M.
Gasoline content, net	1.50 gal. per M.
Producing approximately	15,000 bbl. per da.

Third Test

Trap pressure	15 lb. per sq. in.
Well pressure	180 lb. per sq. in.
Gasoline content, gross	4.40 gal. per M.
Gasoline content, net	2.60 gal. per M.
Volume of gas	6,000,000 cu. ft. per da.
Producing	3,000 bbl. per da.

Fourth Test

Trap pressure	60 lb. per sq in.
Well pressure	180 lb. per sq in.
Gasoline content, gross	4.20 gal. per M.
Gasoline content, net	2.60 gal. per M.
Volume of gas	260,000 cu. ft. per da.

Fifth Test

Trap pressure	30 lb. per sq. in.
Well pressure	150 lb. per sq. in.
Gasoline content, gross	4.60 gal. per M.
Gasoline content, net	2.20 gal. per M.
Volume of gas	500,000 cu. ft. per da.

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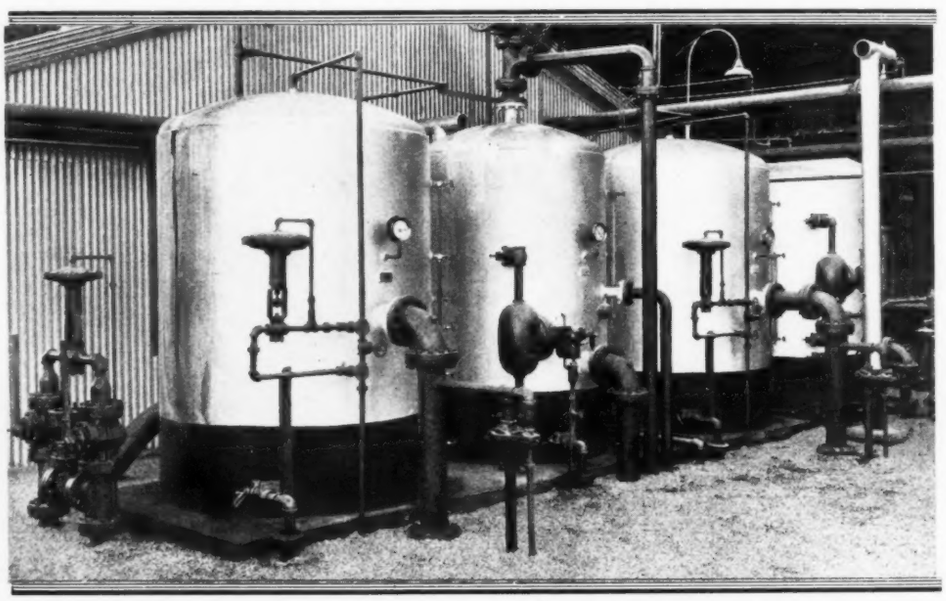
Pressure Control in Modern High Pressure

THE problem of pressure control in modern high pressure absorption plants has been elevated to one of major importance. With certain plants now being designed for pressures as high as 700 pounds, it is manifest that the accurate control of these pressures is vital both for efficiency and safety.

In earlier articles we have investigated the fundamental physical and mechanical considerations of pressure control by means of regulating equipment. It is surely of timely interest to plant designers and operators that the question of proper application of automatic pressure controllers be discussed. In this investigation we are not advocating any particular type of plant design. For the purposes of clarity, however, we will consider the problems of one type of plant. Obviously, there are other successful plants whose flow sheets differ in certain details from this but their pressure control problems are largely the same.



Control equipment on high and low pressure fat and lean oil tanks in a high-pressure absorption plant.

In the example we have taken for analysis, the actual pressure control starts at the oil and gas traps which are supplied by high-pressure wells. These are manifolded together and back-pressure is held on them with the pilot-operated type of back-pressure regulators. It is good practice to install two or more such regulators in parallel and set them so that each is set to hold a little higher back-pressure than the preceding one. This provides a simple way of taking care of increased volumes of gas which may have to be handled. Naturally, when the load is low, one regulator will handle the entire volume, but as the load increases the other regulators go into operation automatically until all the gas volume is being controlled. These back-pressure regulators are set for 500 pounds or more and deliver the excess high-pressure gas direct to the absorption plant.

An added safety precaution against excessive pressures is taken by installing one or more (depending on volumes handled) pilot-operated, single-seated back pressure regulators in parallel with the back-pressure regulators already mentioned. These single-seated regulators exhaust to the blow-off stack in case of an emergency pressure overload. This type of regulator is a new development for this particular service. It combines the virtues of a pilot-operated regulator and a relief valve, but lacks their drawbacks. That is, it possesses the close regulating ability and large capacity of any pilot-operated regulator but its single-seated construction insures the tight shut-off of an ordinary relief valve. Furthermore, it is capable of relieving large volumes without "blowing down" the pressure. These special safety back-pressure regulators are set to hold a back-pressure higher than the highest back-pressure regulator but lower than the regular trap relief safety valves.

High-pressure gas from the traps is usually reduced to about 30 pounds pressure to make it suitable as an operating medium for the pilot valves of the back-pressure regulators. This pressure reduction is commonly executed in three stages to prevent freezing caused by the cooling effect as the high-pressure gas expands in contact with a certain amount of moisture in the air. Special boxes are sometimes built around these three small regulators and the main gas line to act as heat exchangers. Heat radiation from the main gas line is thus utilized to further prevent freezing.

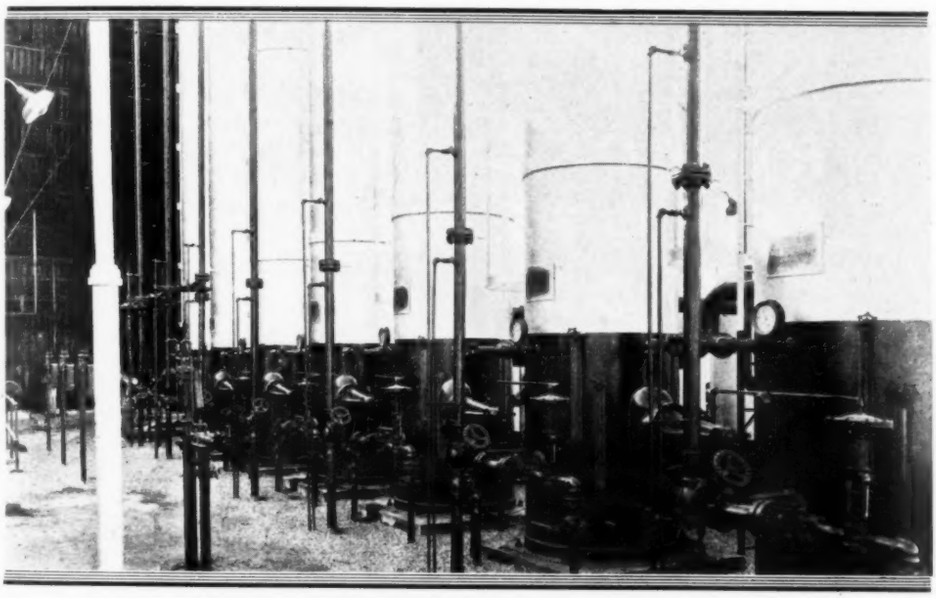
The high-pressure gas from the traps passes through the pre-coolers and into the high-pressure absorbers. A constant back-pressure of 500 pounds or more is held on this battery of absorbers by the use of two pilot-operated back-pressure regulators, the same kind that are used on the traps. These regulators are piped up in parallel to provide for ease in handling large or small volumes of dry gas. Care must be exercised in the choice of all such high-pressure regulators to choose the proper material for the valve plugs and valve seats. With the high-pressure drops present when these last mentioned regulators exhaust to a blow-off stack, Nitralloy, the new superhard metal, has been found excellent. In cases where this dry gas is being sold to commercial gas companies, the pressure drops are not severe and corrosion rather than cutting or wire drawing becomes paramount in

Absorption Plants

By
LOUIS H. BRENDEL
Neilan Co., Ltd.

importance—therefore stainless steel valve trimming is most suitable.

Exact liquid levels are maintained in the absorbers by pilot-operated liquid level controllers. The pilot-operated type is required because the elevated pressures would be difficult or impossible to control with a direct acting liquid level controller in which the float is direct connected by means of a lever and rod to a balanced lever valve. These liquid level controllers must be capable of reducing the fat oil pressure to a point where the undesirable vapors or fixed gases are given up readily in the vent tank. Furthermore, the pilot-operated type insures the full opening of the "fat oil out" valve when necessary with any desired variation in liquid level. The motor valves so operated have been found to afford much greater flexibility in handling widely varying volumes, if they are of the parabolic gradual opening type.



A battery of high-pressure absorbers showing the pilot-operated liquid level controllers used.

As a means of increasing the plant economy and efficiency, high-pressure dry gas is reduced through a pilot-operated reducing regulator and utilized instead of steam for driving the pump turbines. For this service the reduced gas must be heated before its expansion to prevent freezing up the turbines and stripping them of their blades. Normal reduced gas supply pressures for the turbines is from 180 to 250 pounds, and, of course, for turbine service it must be exceptionally constant. Sometimes another pilot-operated back-pressure regulator is employed to hold a 30 to 40-pound back-pressure on the exhaust lines from the turbines.

It is common practice to install a battery of low-pressure traps along with high-pressure ones. The method of holding back-pressure on these low-pressure traps is practically identical except that with the lower pressures (usually from 60 to 100 pounds), direct acting back-pressure regulators are satisfactory. This low-pressure gas may be augmented by low-pressure gas from the field and then goes to the low-pressure absorber. To hold the back-pressure on the low-pressure absorber again requires the pilot-operated type in order to assure constant back-pressures. This regulator exhausts to the low-pressure stack. A line is taken off of the high side of this regulator and a direct acting reducing regulator supplies low-pressure fuel gas to a direct acting boiler regulator, which automatically maintains a constant boiler steam pressure. An improved method of hooking up these two regulators is to take the control connection from the burner side of the boiler regulator. This allows the fuel gas reducing regulator to function only when it is actually required. In cases where the fuel gas supply pressures are high it is desirable to employ a pilot-operated type of boiler regulator.

Feed water pressure to the boilers is automatically controlled by means of an excess pressure pump governor which is installed in the steam line to the feed pump and in this way controls the pump speed.

Returning to the low-pressure absorber, we find that at the lower pressures here encountered, we are able to use the ordinary direct connected liquid level controller satisfactorily on the fat oil cut.

Fat oil from the high and low-pressure absorbers goes respectively to the high and low-pressure vent tanks. The regulation and liquid level control are accomplished in exactly the same manner on both these vessels. On the high-pressure vent tank back-pressure is held by a direct acting regulator which is set to maintain a pressure sufficiently great to force the fat oil through the heat exchangers, preheaters and into the stills against the still operating pressure. Ordinarily, a direct connected liquid level controller will be found satisfactory because the float operates on fairly cold, heavy oil, while the valve is small with a low-pressure drop. Should a large valve be required, then a pilot-operated liquid level controller should be used.

The only difference between the low-pressure and high-pressure fat oil vent tanks, in so far as they are controlled, lies in the difference in their relative back-pressures and the performance of the liquid level controllers.

A direct acting liquid level controller maintains the level in the low-pressure fat oil vent tank by throttling the discharge of the fat oil pump.

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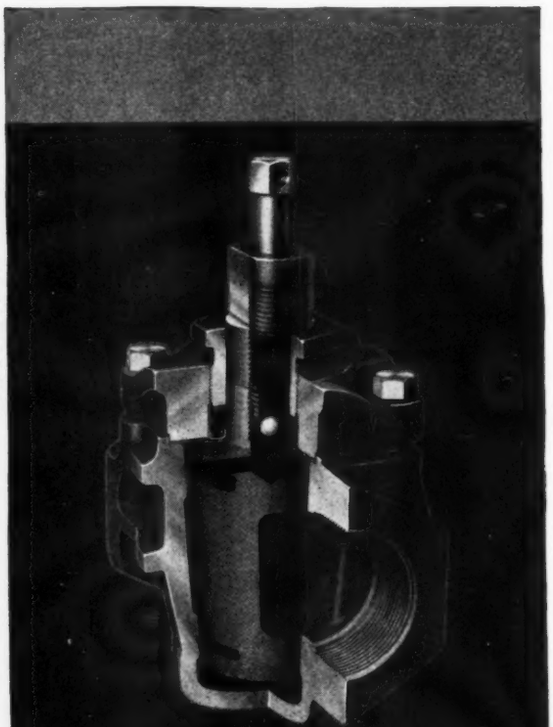

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The fat oil lines from both the high and low-pressure vent tanks join, pass through the heat exchanger and into the secondary fat oil vent tank located just ahead of the still preheaters. Vapors generated in the heat exchangers are separated and passed directly from this vent tank into the still. A special application of a direct acting liquid level controller is made use of in controlling the pressure and liquid level in this vent tank. This application differs, in that the balanced lever valve in this case is installed in the vapor line from the tank to the still, whereas, normally, such a valve is placed in a liquid line. As the fat oil level rises in this vent tank the float closes the balanced lever valve in the vapor line. This permits the vent tank pressure to build up sufficiently to force the fat oil out of the vent tank, through the preheaters and into the still.

The lean oil level in the still is controlled by a remote type of pilot-operated liquid level controller. The diaphragm motor valve in this case is installed in the line between the gravity exchangers and the lean oil surge tank and controls the outflow of lean oil. From the lean oil vent tank the lean oil is picked up by the lean oil pumps and forced through the high-pressure heat exchangers and the lean oil coolers, and then into the high-pressure secondary lean oil vent tank. On this vessel a direct acting back-pressure regulator is utilized for holding the back-pressure necessary to force the lean oil back into the low-pressure absorber and reabsorber. A constant lean oil liquid level is held by means of a direct acting liquid level controller. A booster pump also picks up the lean oil from this high-pressure vent tank and discharges it at a pressure sufficient to force it back into the high-pressure absorbers. This completes the absorption oil cycle and we return to investigate the still more thoroughly.

Steam and hydrocarbon vapors from the still are passed through the gasoline condensers; the condensate flowing to the reflux accumulator. On this vessel an interface direct connected liquid level controller has the ticklish job of automatically separating the water from the raw gasoline. Because of the small difference between the specific gravity of water and gasoline it is often found preferable to employ a controller with a 10-inch float in place of the common 8-inch size. Naturally, the larger float affords additional buoyancy or power for operating the balanced lever valve controlling the outflow of water from the accumulator.

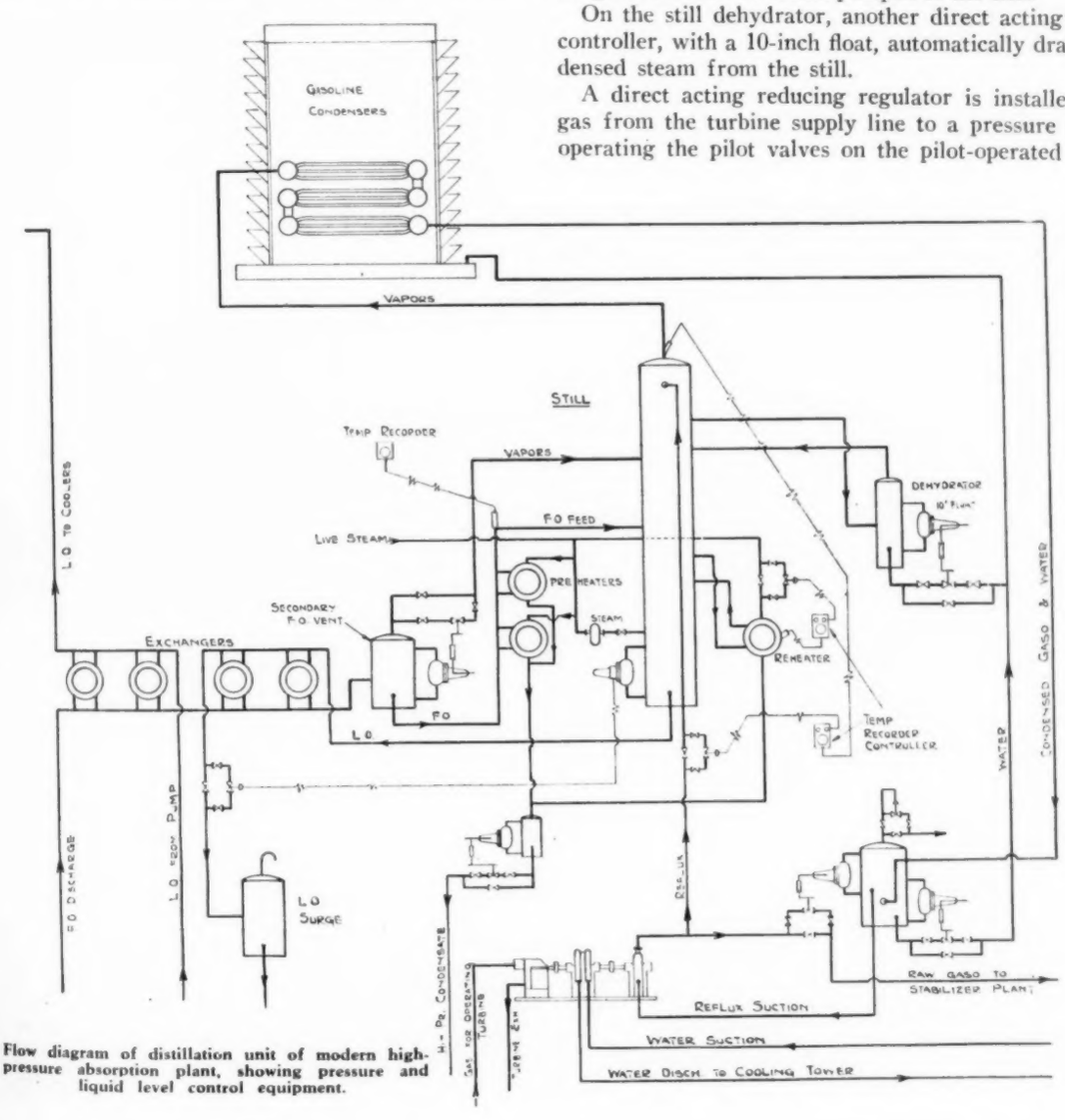
Due to its higher specific gravity, the gasoline forms a floating layer on top of the heavier water which settles to the bottom of the accumulator. A second direct acting liquid level controller is installed near the top of the accumulator and this controls the level of the raw gasoline by throttling a balanced lever valve in the excess gasoline line to storage.

The working pressure on the distillation unit is maintained by a direct-acting back-pressure regulator installed in the vapor line from the accumulator.

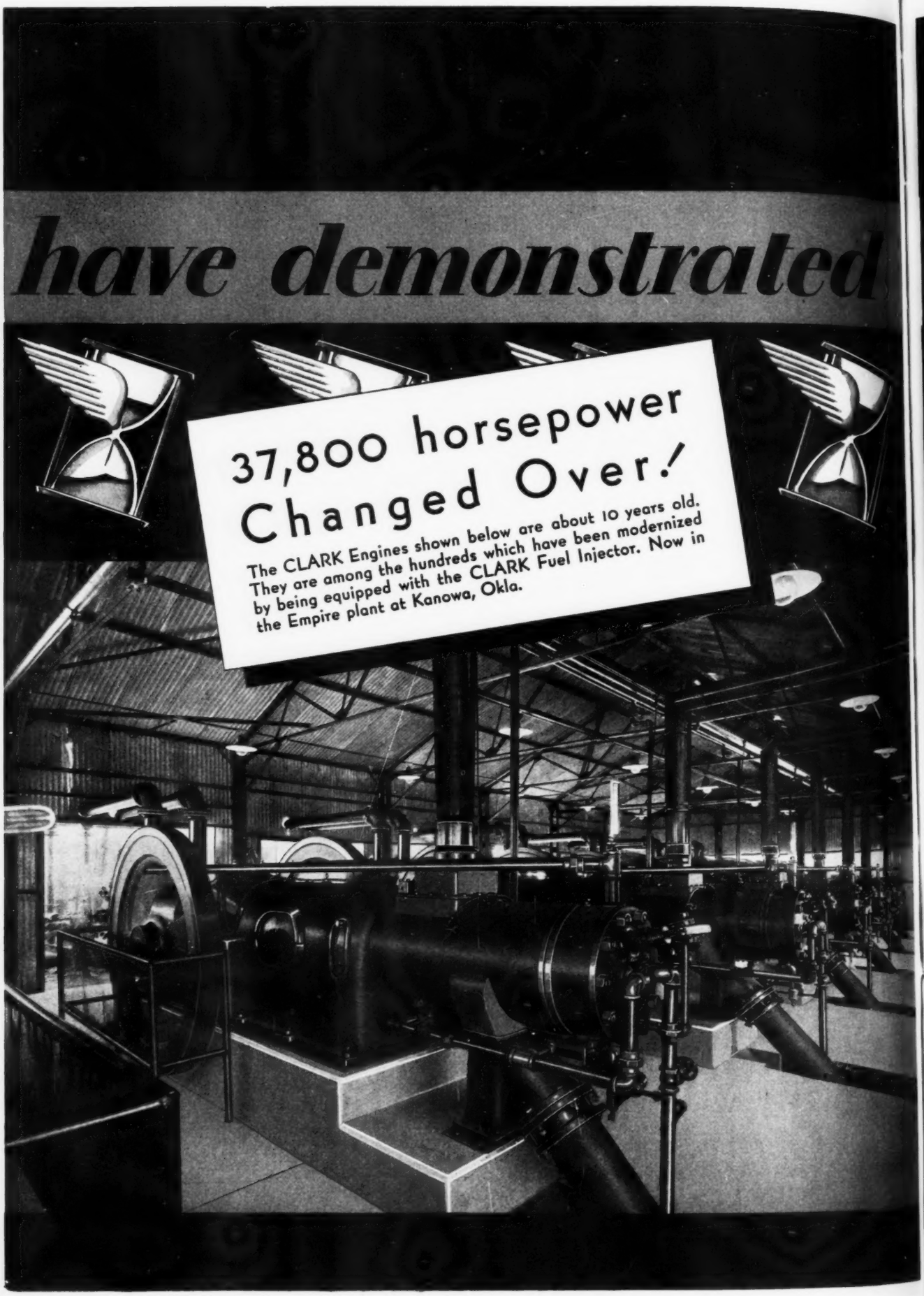
A diaphragm motor valve, actuated by a recording temperature controller, controls the top temperature by throttling the amount of reflux pumped to the still.

On the still dehydrator, another direct acting liquid level controller, with a 10-inch float, automatically drains the condensed steam from the still.

A direct acting reducing regulator is installed to reduce gas from the turbine supply line to a pressure suitable for operating the pilot valves on the pilot-operated liquid level



Flow diagram of distillation unit of modern high-pressure absorption plant, showing pressure and liquid level control equipment.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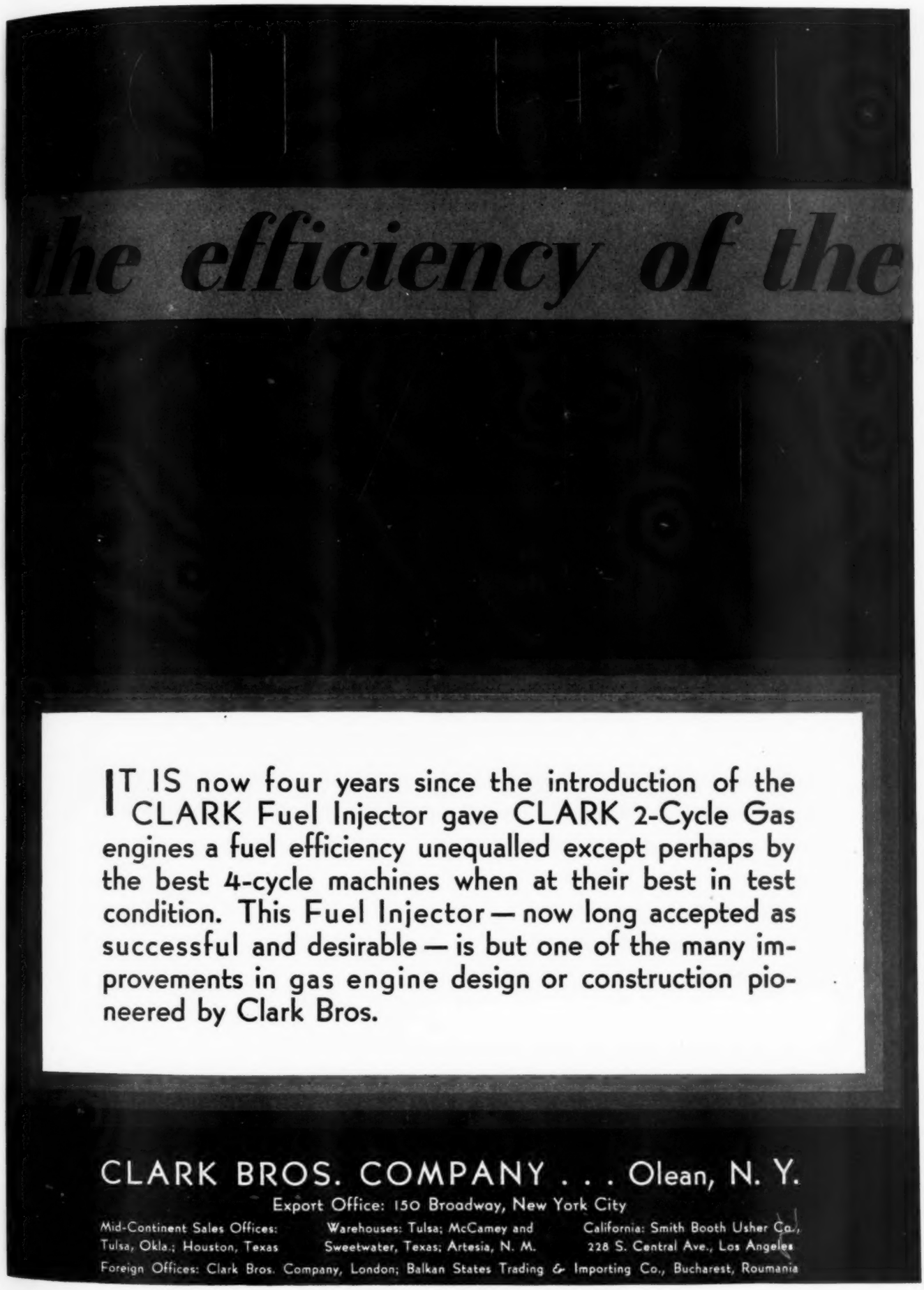

IT IS now four years since the introduction of the CLARK Fuel Injector gave CLARK 2-Cycle Gas engines a fuel efficiency unequalled except perhaps by the best 4-cycle machines when at their best in test condition. This Fuel Injector — now long accepted as successful and desirable — is but one of the many improvements in gas engine design or construction pioneered by Clark Bros.

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controllers and the pilot-operated temperature controllers.

The raw gasoline from the absorption plant usually goes to a stabilizer plant. Lack of space, however, prevents our dealing with the pressure control of a stabilizer unit at this time.

The proper operation of the modern high-pressure absorption plant is largely dependent upon the accurate functioning of the pressure and liquid level control equipment. Because this is true, much research and effort have been devoted toward the perfection of this regulating equipment. Similarly, to obtain satisfactory results, extreme care must be exercised in the selection of the necessary type and size of regulating or control equipment for each particular service. When a plant is being designed, it is always wise to call in a regulation engineer experienced in the peculiarities of the various types of devices, their capacities under different operating conditions and a thorough knowledge of plant processes and their operation. It may be interesting for us to note what may be expected from the different types of controllers, and, at the same time, what are the inherent limitations. As you know there are but two basically different types of pressure regulators. (1) The direct acting type—so called because the controlled pressure exerts its force on the diaphragm, which is directly connected to the valve plug. (2) The pilot-operated type—the same as type (1) except that the controlled pressure actuates a pilot valve which supplies the operating pressure to the main diaphragm. The direct acting type is simpler and less expensive than the pilot-operated type, but its limitations preclude its use in many cases. For service controlling pressures below 150 pounds, where a fairly constant volume must be passed, the direct acting type will be found satisfactory. However, for controlling pressures above 150 pounds, or even for lower pressures where the volume varies widely and close control is required—the pilot-operated type of regulator must be used. On the other hand the use of a pilot-operated regulator, with the exception of certain pressure loaded diaphragm types, is not satisfactory for lower pressures than 10 pounds. This is because pilot-operated types at these low pressures may tend to "flutter." The inherent sluggishness of all low-pressure service, the proportionately large pipe line drops, and also the small differential operating pressures on the pilot valve diaphragm cause this.

These tendencies of pilot-operated and direct acting regulators are not given as positive rules. There are frequent exceptions which demand that each particular problem and solution be studied and separately diagnosed. Normally, the same factors apply, whether we are selecting reducing or back-pressure regulators. As we have found, however, practically all the regulators in the high-pressure absorption plant are for holding constant back pressures.

The pilot-operated type should always be used where it is desired to locate the fluid valve at some remote point such as was described for use at the bottom of the still column, with the diaphragm valve between the gravity exchangers and the lean oil surge tank.

All of the regulating and control equipment herein considered is the latest design in which non-corrosive, stainless steel ball bearings and valve stems are used to prevent corrosion and friction. Such pressure control equipment is exceptionally reliable and sensitive. From the foregoing investigation it will be seen that the modern high-pressure absorption plant is dependent in a large measure on the proper regulating and control equipment. This embodies improved design, suitable type for the service and, what is equally important, the correct size for the volume and pressures to be handled.

In our next article it shall be our privilege and pleasure to consider the pressure control problems in a present-day refinery.

Much Welding Done Last Year

THE last five months of 1930 have shown many advances in the welded field joints of pipe lines since this method was first adopted several years ago. During the past six months the Welding Engineering Co. of Bartlesville, Okla., completed an important percentage of pipe line work on large diameter gas lines. The increased use of electric welding on large diameter lines has been caused by the advent of the heavily-coated rod and development of the shielded arc. By the use of this new process, great strength and ductility have been obtained. In the 452 miles laid, there were over 40,000 welds. Most of this pipe was 20 to 24-inch in diameter. The following lines were welded during the period mentioned:

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Missouri-Kansas Pipe Line Company Lateral Lines in the Texas Panhandle, 24 miles of 18-inch and 20-inch welded and coupled.

United Gas Company, 90 miles between Refugio and Kenedy, and Converse and San Marcus, Texas, 12-inch, 16-inch and 18-inch welded and coupled.

The Continental Construction Corporation (Chicago Line), 306 miles in Texas, Oklahoma, Kansas and Iowa, 24-inch welded and coupled.

In addition to the above mileage completed in 1930, the Welding Engineering Company has uncompleted contracts of welding totaling 547 miles.

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PROGRESS *in* STUDY *of* Pipe-Line Corrosion

By STANLEY GILL, *Research Dept., Gulf Oil Corp.*

INTRODUCTION

THE work which is being done in the investigation of the soil corrosion of buried pipe-lines and methods for its prevention may be divided into the following classes:

A. Basic study of the nature of soil corrosion.

B. Attempts to develop a simple means for pre-determining the corrosive action of soils upon pipe lines.

C. Comparison of metals to determine which will offer the greatest resistance to soil corrosion.

D. Economic studies to determine the most efficient methods of investment in pipe line protection.

E. Development of protective methods.

Increasing interest is being manifested in all of these lines of investigation, and much progress is being made. In the past, work in the field of soil-corrosion has been hampered by the fact that investigators were not in touch with work being done by others; this condition is being obviated, in large measure, by the splendid Soil Corrosion Conferences which have been held, under the leadership of Mr. K. H. Logan, by the United States Bureau of Standards. These Conferences have brought together the most active students of soil corrosion, and have resulted in a very valuable interchange of views.

It is to be hoped that work now being carried on in all parts of the country will result in a useful and profitable understanding of the nature of soil corrosion. Such a knowledge is a necessary basis for the practical solution of the problem.

FROM the standpoint of the investigator who is concerned with the operation of a pipe line system, study of the basic nature of soil corrosion is, necessarily, of far less importance than is the development of methods for protecting the lines. It must be recognized, however, that a final solution can be reached only after the physical and chemical phenomena involved are clearly understood.

For this reason, much importance must be attached to studies which deal with the phenomena of soil corrosion.

Unfortunately, very few investigators have approached the study of soil corrosion in a rational and scientific manner. Most have been preoccupied with an attempt to locate a panacea; to correlate the corrosive effect of soils with some single, simply-determinable factor. Development of a true picture, in which the numerous factors which are involved in soil corrosion will be placed in the proper relation to one another, will eventually result from an unbiased study of all of the factors which enter into soil corrosion. The work which is being done on individual factors should be regarded as laying the foundation for a true understanding of soil corrosion phenomena — an understanding which must be arrived at a little at a time, and which will not over-emphasize one characteristic of soils to the exclusion of others which are equally important.

Figure 1
Deep pitting of pipe in oil-soaked soil. Such corrosion is caused by combined action of the oil and the soil and takes place with great rapidity. It is not a function of soil composition.

The corrosive action of soils is dependent upon a large number of factors.

The reactions which are involved are more or less complex, and no single factor controls the nature and extent of corrosion in all cases. It is not within the scope of this article to enter into a theoretical discussion of the numerous factors which are involved. It is sufficient to point out the fact that data are being accumulated which will eventually result in an intelligent understanding of the numerous phenomena which are involved in soil corrosion action.

Predetermination of Soil Corrosion

Much effort is being expended in efforts to develop simple means for determining, in advance of the installation of a pipe line, the severity of the corrosive action to which it will be subjected. Any method which would accomplish this would be of considerable practical value, since it would make possible the most efficient utilization of protective methods.

Unfortunately, it is doubtful if a simple and economically applicable method for predetermining the corrosive effects of soils can be developed. There are two outstanding difficulties in the way of practical application of such a method.

A. Soil corrosion is an ex-

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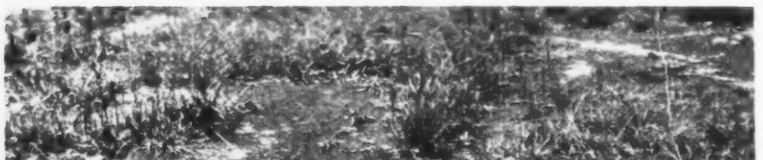

Figure 3
Set-up for field measurement of "long line currents."

tremely complex phenomenon. Involved in the reaction are a large number of factors, any one of which may control the corrosive action in a given case. Thus no one factor will consistently correlate with actual corrosion experience; the influence of a given factor may preponderate in certain cases and be overshadowed in others. By a rather complex combination of factors it is possible to predict corrosive action with considerable accuracy; however, the amount of work required is such as to deprive the process of practical value.

B. It is a familiar fact that, in most soils, corrosive action is extremely "spotted." Seldom is a uniform corrosion experienced by as much as one hundred continuous feet of the length of a pipe line. (Note: There are, of course, exceptional conditions which result in a uniformly severe corrosion over a long length of line. Such conditions are found in salt marshes, swamps, salt-water ditches, cinder fills, alkali flats, etc. They are readily recognized on the basis of experience, and no method of predetermination, beyond that afforded by inspection and experience, is needed to predict their corrosive effects.) The fact that serious corrosion is confined to "hot spots" indicates that a method of predetermination to locate these "hot spots" should be applied to samples of soil taken at very frequent intervals along the course of a projected pipe line. Hence only an extremely simple and rapid method of predetermination would possess practical applicability; the expense of surveying a right-of-way by any but the simplest method would be absolutely prohibitive.

These difficulties are not, in all probability, insuperable; they do, however, make it extremely doubtful that a method which combines reasonable accuracy of prediction with economic feasibility can be devised. Certainly no such method has been brought forward up to the present time.

Thorough discussion of the numerous methods which have been proposed for predetermining soil corrosion is not warranted. The lines which are being followed in these investigations are briefly outlined below:

Soil Types

The Bureau of Soils of the U. S. Department of Agriculture has carried on splendid work in the classification of soils. The results of this work are incorporated in soil survey bulletins in which the types of soils are accurately described and located. From these maps it is sometimes possible to obtain a useful estimate of corrosion possibilities. Such an estimate is not at all adequate to locate "hot spots" in any detail—the variations which control the corrosion on any single joint of pipe are too slight to be determined by a general survey—but broad, general tendencies may be recognized. Thorough study aimed at a correlation of corrosion with results of the Bureau of Soils' surveys would doubtless prove of great value and would produce data of considerable practical value. The correlation should, by all means, be based upon the corrosion experience of existing pipe line systems, rather than upon isolated tests, and could be carried on through a statistical analysis of the corrosion records of large pipe line companies.

Electrical Resistivity

Electrical resistivity is used as a measure of soil corrosivity in many of the proposed methods. This factor is easily determined and is, in extreme cases, one of the controlling factors in soil corrosion. The methods which are used for determination of soil resistivity are legion and range from the accurate earth-current meter to the simple "guessing sticks" devised by Mr. Shepard[1] of the Bureau of Standards, and include such fantastic procedures as the so-called "corrosion tests" in which a piece of pipe, buried in a sample of the soil in question, is made the anode of an electrolytic cell subjected to a definite voltage.[2] Actually

[1] Shepard: Bureau of Standards Journal of Research, 6, 683 (April, 1931).
[2] A method of this type has been somewhat extensively employed in California.

Figure 2
Typical corrosion from oil-soaked ground. Note that the original mill-scale surrounding the pits is absolutely intact.

electrical resistivity correlates with corrosion only in extreme cases. Soils of very low electrical resistivity are, frequently, corrosive; soils of extremely high electrical resistivity are, usually, non-corrosive. This might be restated as follows: Soils containing a considerable quantity of soluble salts are, frequently, corrosive, while soils which do not contain salts (such as clean sands) are, usually, non-corrosive. In this form the truth of the statement is obvious; it applies only to extreme cases. In the intermediate range, in which most soils fall, corrosion and electrical resistivity do not correlate.

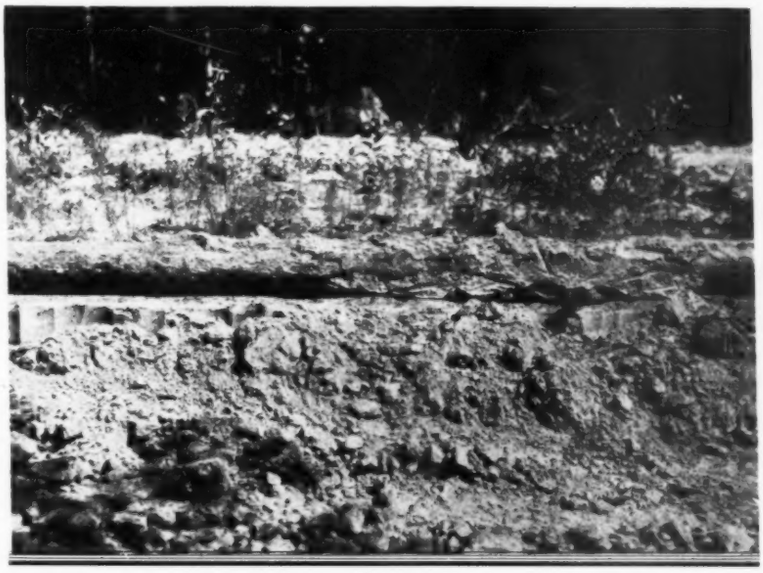

Figure 4
Typical highly corrosive "alkali knoll" of the Texas Gulf Coast. The soil is sandy and contains practically no dissolved salts. The electrical resistivity is high.

Chemical Analysis of Soils

Attempts to correlate soil corrosion with the chemical analysis of soils have been made by a number of investigators.[3] Such methods have involved both analysis of the soils themselves and examination of water solutions obtained by extraction under various conditions. The procedure involved in making such chemical analyses is so complicated as to deprive them of value as practical methods of predetermining soil corrosion. In addition, they cannot be correlated with soil corrosion, since the influence of chemical composition is frequently overshadowed by other factors.

"Long-Line Currents"

Recognition of the fact that pipe-lines carry electric currents of measurable magnitude, which are apparently due to the galvanic action of soils, is due to the work of Mr. K. H. Logan. These so-called "long-line currents" have been investigated with a view to possible corrosion correlations.[4] No relationship which is sufficiently consistent to be of practical value has been found to exist.

[3] Logan: Reprint No. 27-10 and 447 of the American Foundrymen's Assn.
Logan: Bureau of Standards Journal of Research, 3, 275 (1929).
Parker: Petroleum Engineer, 2, 79 (1930).
Smith: Western Gas, 7, 30, 65 (1931).
Smith: Gas Age-Rec., 66, 987 (1930).

[4] Logan, Rogers & Putnam: Proceedings 10th Annual Meeting American Petroleum Institute (1929).
Gill & Rogers: Oil and Gas Journal, June 5, 1930, p. T158.
Shepard: Bureau of Standards Journal of Research, 6, 683 (April, 1931).

Hydrogen-ion Concentration

No consistent correlation has been found between the hydrogen-ion concentration of soils and their corrosive action. This is apparent from certain results published by Mr. Logan;[5] of the forty-eight soils included in his tests, the two most corrosive were, by a peculiar coincidence, the most alkaline and the most acid soils of the series. This utter lack of correlation has been found in other tests. It is not surprising that this is true; very few soils have an acidity greater than that corresponding to a pH of 5, or an alkalinity greater than that corresponding to a pH of 8. In the practical sense the range from pH = 5 to pH = 8 is substantially neutral; even in the case of corrosion by aqueous solution, variation of pH within this range has practically no effect upon corrosion rates.[6]

Correlations closer than those obtained with pH are said to obtain between corrosion and the total acidity of soils.[7] There is no theoretical reason to indicate that this should be true, and the data which have been published do not indicate any great consistency of correlation.

Figure 5
Typically corroded pipe from an "alkali knoll."

Moisture

Some work is being done upon the influence upon corrosion of those soil characteristics which control the absorption, action and retention of water. Several different lines of investigation are being pursued. No results have been published and no definite correlations have been established. Fundamentally the presence of water is the only factor which is universally essential if soil corrosion is to proceed; for this reason valuable information can be obtained by studies of the relationship of soil moisture to corrosion. However, it is doubtful if such studies, excepting those which deal with broad, general considerations of topography,

[5] Logan: Preprint No. 27-10 of the American Foundrymen's Association.

[6] Whitman, Russell & Alteri: Industrial and Engineering Chemistry, 16, 665 (1924).

[7] Holler: Industrial and Engineering Chemistry, 21, 750 (1929).

rainfall, etc., will prove of practical value in the predetermination of soil corrosion.

The Putnam Method

Of the proposed methods for predicting the corrosive action of soils, only one evidences a reasonably complete appreciation and understanding of the fundamental electrochemical reactions which are involved. This is the procedure which has been developed by Mr. J. F. Putnam.[8] A description of the method, and of the rather ingenious means by which it was developed, will be found in the paper cited. Although Mr. Putnam's basic reasoning is entirely sound, he neglects some factors which may be of great importance and which may invalidate the results of his tests in many cases. Unfortunately, Mr. Putnam has not published comparisons of the results of his test with actual soil corrosion experience; hence the consistency of the correlation cannot be stated.

In summary it may be said that there is at present no simple method of proven value for predetermining the corrosive action of soils. It is unfortunate that procedures of this type are being commercially exploited before their value has been established by adequate comparison with actual corrosion experience. Common-sense criteria should be applied in evaluating proposed methods of surveying to predict corrosion. The following points are particularly noteworthy:

A. A method for correlation, to be of practical value, should correlate in a substantial majority of cases. Thus, a method which correlates in 50 out of 100 cases, and which fails to correlate in 50 cases, is absolutely worthless. A method which correlates in 75 out of 100 cases and which fails in 25 cases is only 50 per cent efficient and will fail to locate 50 per cent of the "hot spots."

B. The cost of the method of prediction should be well below the savings which a successful prediction would accomplish.

C. "Scientific" methods of prediction should not be given credit for predicting facts which would be obvious if they were not used. For example, the statement that "soils having a resistivity of 100 ohm-centimeters or less are usually corrosive" is without value, since so low a resistivity is found only in highly saline soils, and since the corrosive nature of such soils is recognizable, without recourse to resistivity measurements.

Economics of Pipe Line Protection

Much has been written on the economics of pipe line protection[10], and an appreciation of the importance of economic study of protective methods has resulted in substantial savings to the pipe line industry.

There is, however, a tendency to go to extremes in the elimination of unnecessary expenditure for protection of pipe lines. Such a procedure results from an inadequate study of the economic factors involved. An economically controlled protective program does not, necessarily, imply an unprotected pipe line, but rather results in an efficient utilization of protective methods.

A paper on "Economics of Pipe Protection" by Mr. E. P. Bly is announced for the June, 1931, meeting of the American Petroleum Institute Division of Production. Mr. Bly has been a pioneer in the application of economic principles to the protection of pipe lines, and his paper will be of exceptional interest and value.

Pipe Line Coatings

Tests of Coatings

Two series of tests, which will contribute greatly to knowledge of the performance of coatings for buried metals, are

[8] Putnam: Proceedings of 11th Annual Meeting of the American Petroleum Institute (November, 1930).

[10] Weidner: Proceedings 7th Annual Meeting American Petroleum Institue (1926).
Scott: 9th Annual Meeting American Petroleum Institute (1928) and 10th Annual Meeting American Petroleum Institute (1929).
Fitzgerald: 10th Annual Meeting American Petroleum Institute (1929).
Gill: Petroleum Engineer, Mid-Year, 1930, page 119 and Oil Weekly, March 14, 1930, page 65.

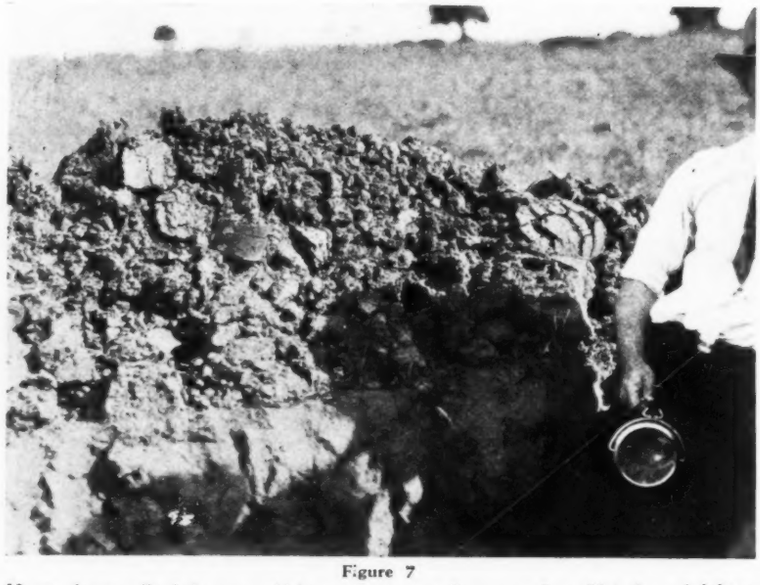

Figure 7
Heavy clayey soil of the type which causes severe soil stress action. Note how shrinkage of the lump has caused them to crack.

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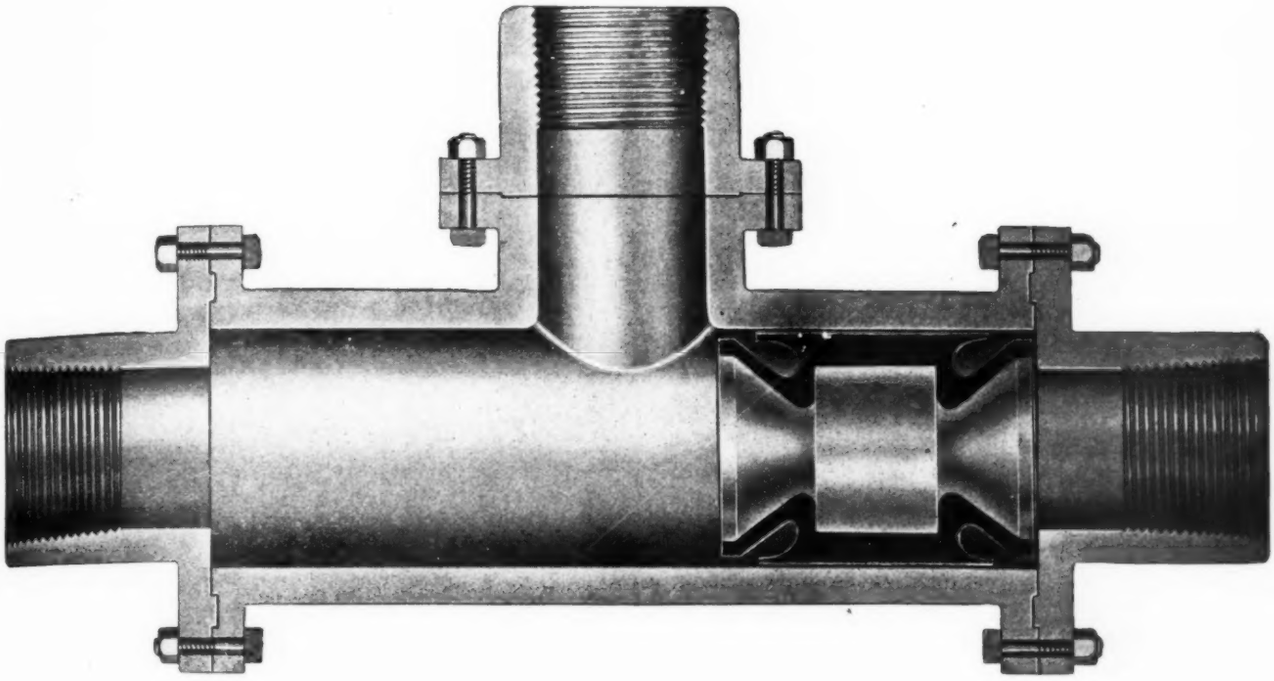

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being conducted through the agency of the United States Bureau of Standards. The first of these are sponsored by the American Gas Association, and are being conducted by Dr. Scott Ewing.[11] They involve burial, in a number of locations, of pipe nipples coated with the materials under test. By themselves, nipple tests are of doubtful value, since the performance of coatings, on nipples, has not been adequately correlated with their performance on actual pipe lines. For this reason, the value of the American Gas Association's tests will be greatly enhanced by the results of tests which are being conducted by Dr. Gordon N. Scott. Dr. Scott's tests[12], which are sponsored by the American Petroleum Institute, involve the application of a group of coatings selected to include all important types, upon working pipe lines. Nipples, coated with the same materials, have been buried alongside the pipe lines. By this means, accurate comparison of the behavior of the coatings on nipples and in actual service will be possible.[13] These data will be of much value in the interpretation of the results of the American Gas Association's tests.

Tests such as those which are being carried on by Dr. Ewing and Dr. Scott will, in time, supply invaluable data upon the nature and performance of pipe line coatings. The data thus obtained will, it is hoped, result in great improvement in the value of such coatings.

Development of Coatings

Recent development of coating materials has been aimed chiefly at an improvement in the resistance of such materials to soil stress action. Appreciation of the very great importance of this phenomenon is due to the work of Dr. Scott. Improvements which have been made since Dr. Scott described the nature of soil stress phenomena and showed their importance in the break-down of pipe line coatings have resulted in a very great increase in the value of the coating materials which are available.

Particular noteworthy progress in the reduction of distortion effects has been made by the manufacturers of pipe line enamels. All of the leading manufacturers of coating materials of this type are engaged in intelligent and practical studies to increase the resistance of their material to soil stress action. The work which is being done is taking the form of modifications in the quality of bituminous materials used, and in the fillers which are employed, in order to impart to the finished coatings increased mechanical strength.

Figure 6
Typical view in salt marsh on the Texas Gulf Coast. This territory is highly corrosive.

Some of the enamels which have been developed with the primary object of resistance to soil stress have been made so hard and brittle as to deprive them of the proper adhesion and resistance to breakage in handling. However, such troubles are being overcome and there are now on the market a number of enamels which will afford excellent protection.

Little or no progress has been made in the development of coatings outside of the enamel class. There exists a very real and pressing demand for coatings of high protective value which can be applied to "hot spots" without the heating equipment and trained crews which are necessary for the proper use of enamels. Some work is being done along this line by various manufacturers, but there is as yet no easily applied coating material which will afford certain protection for a period as long as five years.

Certain rather elaborate coatings have been advocated for use in "hot spots." Methods for the application of asphaltic mastics have been developed to a point where very good coatings of this type can be applied. It seems certain that such coatings will possess a very great protective value, but practical considerations limit their utility to limited lengths of line under very special conditions. It is probable that future developments in the application of mastics will widen their field of usefulness. In time, coatings of this general class may be expected to find wide use.

Interesting strides have been made in the use of concrete for coating pipe lines. The cement gun has been used with considerable success, and practical and ingenious movable forms for the casting of concrete or mortar coatings have been developed. A thorough study of the application of concrete coatings to pipe lines has been conducted by the Portland Cement Association. This has resulted in specifications for mixes which will give coatings of maximum density and mechanical strength. The use of a vibrator for equal maximum density is advocated, and this should produce coatings of great protective value. Costs of application of these concrete coatings are said to be surprisingly low, and far below the costs of previous work along these lines. Concrete coatings, if properly applied, will afford protection

[11] Ewing: Oil & Gas Journal 28, 46, (1930).
[12] Scott: 11th Annual Meeting American Petroleum Institute (1930).
[13] Scott: Oil & Gas Journal, 29, 147, (1931).

indefinitely. They possess, of course, the disadvantage of making the cost of salvaging the pipe prohibitive, in the event the line must be abandoned. Practical use of concrete coatings is limited to "hot spots" or to sections of permanent trunk lines which are exposed to especially severe corrosive conditions.

Much study is being devoted to the development of new wrapping materials to protect coatings against soil stress. Tests are being run on a very great number of materials in an effort to develop wrappings of reasonable cost which will successfully withstand mechanical distortion. The present status of the experiments with wrapping materials is outlined by the writer in a recent paper[14]. Up to the present time, none of these new wrapping methods has adequately demonstrated its value but developments of great interest are to be anticipated. Generally speaking, developments during the past year have resulted in appreciable improvement in the performance of pipe line enamels.[15]

Conclusions

As a summary of the present status of soil corrosion investigation, the following general statements may be made:

A. From the standpoint of basic investigation of soil corrosion phenomena, there is altogether too little thorough study of the true nature of soil corrosion. Most of the effort which is being expended in the investigation of soil corrosion is being devoted to an effort to discover some simple method of predetermining corrosive action.

B. These efforts to establish methods of prediction, although they are of great interest, are too often carried on from the wrong angle. That is, there is a tendency to find correlations even where such do not exist in a practically valuable majority of the cases investigated. There is a considerable tendency to overemphasize the value of correlations arrived at by some laboratory method, but which could have been reached by far simpler methods of attack.

C. The studies of soil corrosion are too frequently based upon inadequate corrosion data. Greater advantage should be taken of the very complete corrosion records which are available on certain large trunk pipe line systems, and studies of soil corrosion should be tied to such practical data, rather than to the results of small-scale tests.

D. Considerable progress has been made in the improvement of pipe line enamel coatings and in development of special coatings, such as asphaltic mastics and cement or concrete. A similar statement applies to wrappings for protecting pipe line coatings against soil stress. However, very little attention is being devoted to the improvement of coatings of simpler types and lesser expense, and developments along this line would be of great value to the pipe line industry.

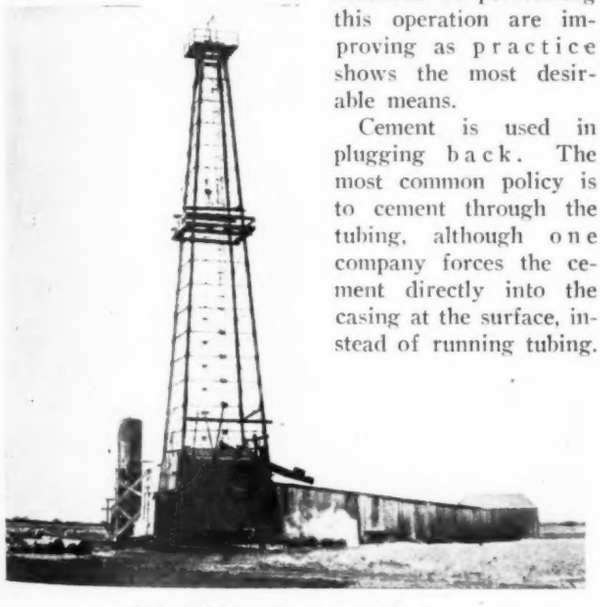
On the whole, it may be stated that much excellent work is being done along the lines of soil corrosion and the prevention of soil corrosion, and that gratifying progress is being made.

[14] Stanley Gill: Oil Weekly, May 8, 1931, page 40.
[15] For general comparison of coating materials, see Stanley Gill; Petroleum Engineer, Mid-Year 1930 Number, page 119 and Oil Weekly, March 14, 1930, page 65.

New Method of Plugging Back and Shooting In The Lime Area of Oklahoma City Field

PLUGGING back and shooting upper horizons to obtain natural gas production is becoming a general practice in the Arbuckle lime area of the Oklahoma City field. Methods of performing this operation are improving as practice shows the most desirable means.

Cement is used in plugging back. The most common policy is to cement through the tubing, although one company forces the cement directly into the casing at the surface, instead of running tubing.



Early Oklahoma City lime producer.

Ripping the pipe before shooting the well has not proven practical since several holes have bridged when this practice was followed. Therefore, the most generally used practice is to shoot the well before ripping the pipe.

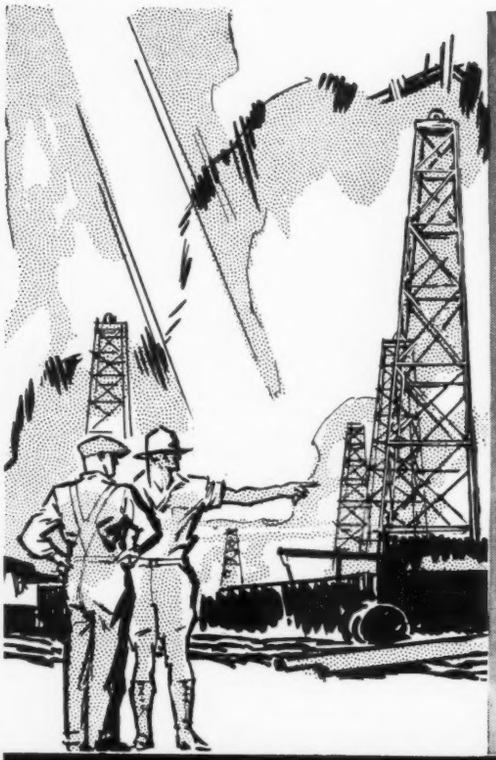
The shot must be large enough to rupture the casing. The best results have been obtained when the shots are of 100 quarts or more. Dry hole shooting predominates, although some good wells have resulted when shot with the hole full of water. It is the usual practice when dry hole shooting to have the shot covered with water.

There are five upper horizons, all of which carry gas production in different parts of the field. The Prue sand is at 6,100 feet; the Oolitic at 5,400 feet; the Layton from 4,800 to 4,900 feet; the Tonkawa at 4,100 feet, and the Hoover at 4,000 feet.

Whenever the formation to be shot is above the six-inch casing point that string is reclaimed, and the well is produced through the nine-inch pipe. The wells produce from small amounts to as much as 158,000,000 cubic feet.

The Arbuckle lime area is in the center of the Oklahoma City field and is the site of the early completions. Heavy water intrusion has caused many of the wells to go dead, consequently the plugging back for gas production. Production from the majority of remaining lime producers has declined to a low output and the policy of plugging back and shooting the wells for gas production will doubtlessly be adopted to a greater extent in the future.

TWO GREAT D



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DERRICKS

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Moore Challenger ANGLE DERRICK

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Practical Analysis *of* Lubricating Greases

By
DR. WM. T. SIEBER, *Chief Chemist, Waverly Oil Works, Pittsburgh, Pa.*

A SATISFACTORY examination or analysis of lubricating grease is—to say the least—tedious and complicated, even in a laboratory suitably equipped for this class of work. The method recommended by the American Society for Testing Materials gives good and accurate results from a scientific standpoint, but for practical work, in the control laboratory of a grease manufacturing concern, it is quite complicated and time consuming. On account of the small quantity of the sample used for the ASTM analysis, special care has to be exercised in carrying out the different steps of the procedure or else the percentage of error will be great and the identification of the component parts of the grease will be quite difficult. In any event, it behooves the analyst to decompose larger samples of grease so that the necessary identification tests can be more conveniently made.

In the writer's laboratory, which specializes in the examination and testing of all kinds of lubricating greases, the following methods are in use and have proven to give good and reliable results from the practical standpoint. Naturally, no claim is made that these methods are absolutely quantitative, but for control work they give sufficient information as to the nature and composition of the grease. I wish to mention that in referee work or in cases where more exact analytical results are required, and where time is no object, the ASTM method for the analysis of grease is strictly adhered to.

In the following, the writer is trying to give an idea of the methods in use in his laboratory, but on account of the large variety of greases which may be encountered and due to the complexity of the field, he wishes to be excused for any incompleteness which may be noted.

The examination of lubricating greases is composed of two parts:

(1) Physical Part.
(2) Chemical Part.

Under the physical part we classify the following tests:

Consistency.
Melting point.
Color and odor.
Flash and fire point.
General characteristics of more or less physical nature.

The chemical part includes:

Nature and per cent of soap.
Nature and per cent of free fatty matter present.
Nature and per cent of mineral oil.
Nature and per cent of filler.
Per cent of water.
Free acidity or alkalinity.

To expand on the physical and chemical tests we have the following:

Consistency: In the determination of consistency we are using two means of measuring same, namely, the ASTM penetrometer and the MacMichael viscosimeter. The former is used with lubricants having a penetration of 350 mm/10 or less at 77 degrees Fahrenheit. This determination is made on a worked sample of grease and the test is performed as specified by the ASTM. The MacMichael viscosimeter is used with lubricants softer than 350 mm/10 penetration. It is a torsion type apparatus and with two test wires (No. 22 and No. 26) we cover the entire range of soft lubricants, semi-liquid and liquid greases. This test is also run at a temperature of 77 degrees Fahrenheit.

Melting Point: The drop method is being used at this time. The bulb of an accurate thermometer is coated with the grease to be tested and is then suspended freely in an empty test tube which, in turn, is immersed in a light oil. This oil bath is then gradually heated at a rate of 5 degrees Fahrenheit per minute. The temperature is recorded when a drop of grease, having formed on the end of the thermometer bulb, falls to the bottom of the tube. This temperature is noted as the melting point of the grease.

Color and Odor, Flash and Fire Point, etc., are taken in the usual manner and are more or less subject to the personal observation of the chemist.

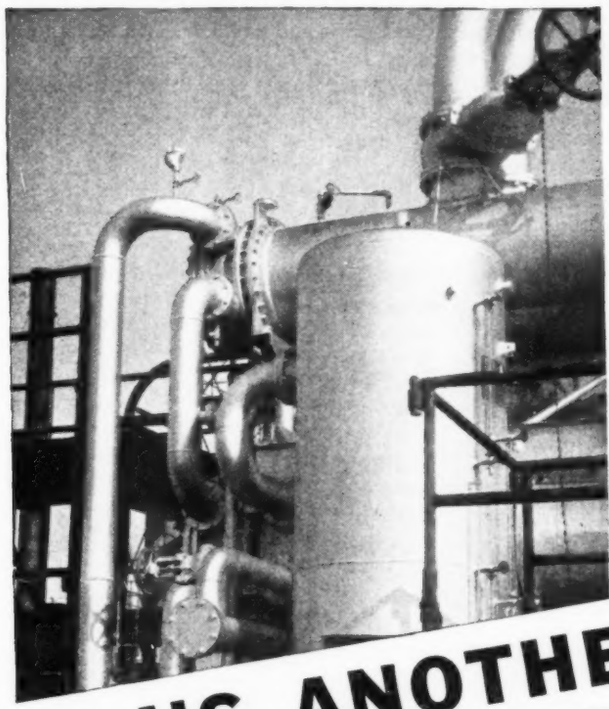
A 200-400 gram sample of the grease, to be analyzed, is extracted with petrolic ether, using a centrifuge to facilitate the separation. The amount of grease is weighed in an aluminum cup, which fits into the centrifuge tube, petrolic ether added, and the grease broken up as much as possible, using a glass rod. In about 12-15 minutes centrifuging time a clean separation is effected and the petrolic ether, containing the mineral oil, free fatty matter and traces of soap, can easily be decanted. Usually 3-4 extractions are sufficient to separate oil from soap. The complete breaking up of the grease in the aluminum cup is very essential as it facilitates greatly the extraction and cuts down the time. The end of the extraction is indicated by the last portion of the petrolic ether being clear and not discolored. I wish to mention that before extracting the grease the sample has to be dehydrated in order to obtain a perfect separation of soap and petrolic ether, for in the presence of water, even in small quantities, emulsion-like mixtures are formed, which can not be broken by centrifugal force. Therefore it is advisable to heat the original sample of grease to a temperature of 105 degrees centigrade for about one hour, which temperature and time are usually sufficient to drive off all the water present.

I wish to mention, too, that it is not at all necessary to weigh the amount of grease (200-400 grams) very exactly. In the writer's laboratory a scale with comparatively low sensitivity is in use, and the results obtained check very closely with the ones obtained by following the ASTM method. On account of the large amount of sample used, the per cent of error is greatly reduced.

The petrolic ether used in the extracting operation is a straight-run gasoline of an endpoint of not over 210 degrees Fahrenheit—shall be neutral in reaction and shall leave no greasy or oily residue on evaporation.

After the extraction of the grease is completed, we have two parts—*the solids "A"* (in the aluminum cup) which contain the soap and filler, and *the liquid portion "B"*, which contains all the mineral oil, and fatty matter, together with traces of soap. The second portion is greatly diluted with petrolic ether.

The petrolic ether solution, containing mineral oil, free fatty acid, fat and traces of soap, is introduced into a tared distilling flask and the petrolic ether distilled off. The distillation is greatly accelerated by bubbling through the distilling liquid a slow stream of natural or any inert gas. After the distillation is completed the flask is again weighed and this portion of the grease is calculated on a percentage basis, "B".



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Tube-Turns are made in 45°, 90° and 180° types.

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TUBE-TURNS

No Thinning of Outside Wall—No Buckling of Inside Wall

When writing TUBE-TURNS, INC., *please mention The Petroleum Engineer*

In order to determine the per cent of mineral oil in "B" by difference, it is necessary to find the amounts of "G", "H" and "K" which are also present in "B". This is done as follows:

To an aliquot part ("G") (weighed amount) of "B" neutral ethyl alcohol is added, warmed and titrated with n/10 alkali solution to a pink color (with phenolphthalein). This gives the per cent of *free fatty acid* and has to be calculated to the original grease.

To determine the amount of soap present in "B" another aliquot part "H" (weighed amount) is washed into a separatory funnel with neutral petrolic ether and decomposed by shaking with dilute hydrochloric acid. This mixture is then washed free of mineral acid by using hot water. Neutral alcohol is then added, shaken thoroughly and titrated with n/10 alkali to pink color of the alcoholic layer, using phenolphthalein as indicator. (This titration is performed directly in the separatory funnel.) In this way the per cent of total fatty acids in "B" is obtained. The amount of soap fatty acids (due to soap present in "B") is obtained by subtracting free fatty acids "G" from total fatty acids. This value must be considered, along with the soap fatty acids contained in "A" in order to get the correct value for the total per cent of fatty acids from soap, originally present in the grease. The per cent of soap can easily be calculated by converting the amount of fatty acids into soap, using a factor.

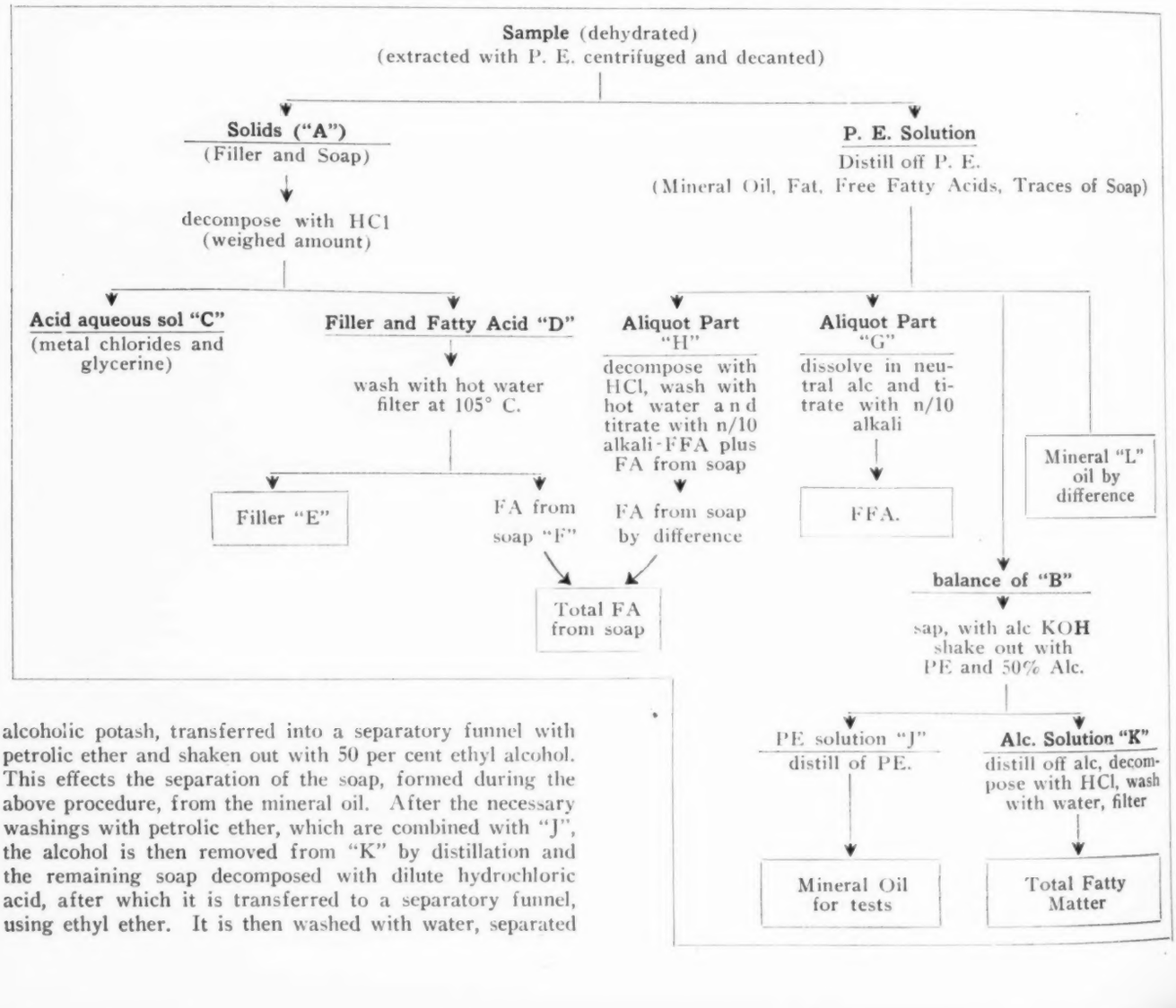
The remaining part of "B", known as "I", is treated as follows in order to obtain the per cent of free fat present in the grease. The whole amount of "I" is saponified with alcoholic potash, transferred into a separatory funnel with petrolic ether and shaken out with 50 per cent ethyl alcohol. This effects the separation of the soap, formed during the above procedure, from the mineral oil. After the necessary washings with petrolic ether, which are combined with "J", the alcohol is then removed from "K" by distillation and the remaining soap decomposed with dilute hydrochloric acid, after which it is transferred to a separatory funnel, using ethyl ether. It is then washed with water, separated and the etherical layer run into a tared beaker, the ethyl ether evaporated and the residue weighed. After identification of these fatty acids, by the usual methods, the per cent of free fat originally contained in the grease can be calculated at this point. Free Fat = K — (G + H) × conversion factor.

The petrolic ether layer from the preceding separation, "J"—after the necessary washings with 50 per cent ethyl alcohol (which are combined with "K"), is introduced into a distilling flask and the same procedure followed as in "B". This leaves a residue of mineral oil, which is then ready to be examined for its characteristics, such as gravity, flash—and fire point, viscosity, etc. The per cent of mineral oil "L" is obtained by difference, that is:

$$L = B - (G + H + \text{free fat})$$

In determining the amount of water present in the sample of grease to be examined, the regular ASTM method is used.

In concluding, it has been our experience that the results obtained in such a grease analysis, seem to be proportional to the adaptability and experience of the operator. Consequently, there is considerable room for alterations and variations of the above procedure, and in the hands of an experienced chemist quite accurate and dependable results are obtained. The calculation of the results of a grease analysis —to say the least—is more or less complicated. There are certain constants involved which may be obtained in different ways, and due to the fact that space will not permit us to explain same, it will be left to the ingenuity and experience of the chemist.


Sample (dehydrated)
(extracted with P. E. centrifuged and decanted)
Solids ("A")
(Filler and Soap)
decompose with HCl
(weighed amount)
P. E. Solution
Distill off P. E.
(Mineral Oil, Fat, Free Fatty Acids, Traces of Soap)
Acid aqueous sol "C"
(metal chlorides and glycerine)
Filler and Fatty Acid "D"
wash with hot water filter at 105° C.
Aliquot Part "H"
decompose with HCl, wash with hot water and titrate with n/10 alkali-FFA plus FA from soap
Aliquot Part "G"
dissolve in neutral alc and titrate with n/10 alkali
Mineral "L" oil by difference
Filler "E"
FA from soap "F"
FA from soap by difference
FFA.
Total FA from soap
balance of "B"
sap, with alc KOH shake out with PE and 50% Alc.
PE solution "J"
distill of PE.
Alc. Solution "K"
distill off alc, decompose with HCl, wash with water, filter
Mineral Oil for tests
Total Fatty Matter

H. N. Blakeslee, safety engineer, American Petroleum Institute.

Progress *in* Accident Prevention ..*in* Petroleum Refineries

By H. N. BLAKESLEE, *Safety Engineer,*
Department of Accident Prevention, American Petroleum Institute

THE question has been asked, what tangible evidence do we have of the value of accident prevention work in oil refineries? Probably the best way to answer this question is by giving the definite experience in accident prevention in certain refineries which have been interested and active in accident prevention work for a period of years and comparing the results with the situation in refineries of the United States as a whole.

One company operating four refineries employing almost 4,000 men, in the year 1929, experienced injuries to employees causing the loss of time from work at the rate of one lost-time accident to each 131 employees during the year. Another company operating some six or seven refineries and employing over 7,000 workers reported one lost-time accident during the year to each 83 employees. Each of these companies has been active in accident prevention work for ten or twelve years.

Statistics gathered by the Petroleum Section of the National Safety Council for the year 1929, covering 80,000 refinery workers, show that lost-time accidents occurred to each 19 men employed during the year. Comparison of the accident experience of these refinery workers (of the industry) with the accident experience of the companies, shows that one company is actually preventing 86 per cent of its share of accidents and the other company is preventing 77 per cent of its share.

During the first six months of 1930, the Petroleum Section of the National Safety Council conducted a contest. In this contest 41 refineries, each employing 480 men, or more, experienced an accident frequency of 12.46 accidents to each one million hours worked. On the other hand, 51 refineries, each employing less than 480 men reported an accident frequency of 32.10 lost-time injuries to each one million hours worked. This comparison seems to indicate as a whole that the large refineries are more definitely interested in accident prevention work than are the smaller refineries. However, during this contest fourteen refineries working less than 480 men went through the contest without a single lost-time accident. This leads us to conclude that where small refineries are as well managed as the larger refineries usually are, accidents are indeed rare.

One small refinery in Pennsylvania first became interested in accident prevention late in 1927. During that year 49 lost-time accidents occurred in the refinery. This included one fatality. During 1930 accidents in this same refinery caused no loss of time by employees from their work. Incidentally, this refinery is considered well managed in every respect.

Advance information on the records of the Petroleum Section of the National Safety Council for 1930 indicates more than 65,000 refinery workers will show an accident frequency rate 31 per cent lower than the rate reported in 1929. During 1930 one out of every 28 refinery workers reported sustained a lost-time injury, as compared with one out of every 19 in 1929.

A pipe railing prevents this man from striking his head against the open window.

The question may be asked, how has this change been brought about in the refineries which have succeeded in reducing accidents. The answer is: A more complete understanding of the work done in the refinery. Of course, mechanical improvement, such as the use of conveyors for handling boxes, cans, drums and heavy material, has contributed to the result by making it unnecessary for men to handle the heavy loads as formerly. Vapor-proof electrical equipment has replaced other types of electrical equipment, thereby eliminating a source of ignition for flammable vapors.

Thought has also been given to the elimination of flammable vapors around distillation equipment, receiving houses, storage tanks, and elsewhere about the refinery. When repair work is to be done steps are taken to see that all

3 GRAPHS *Showing How Increased Compression*

. . . INCREASES POWER

. . . LOWERS HEAT TO COOLING WATER

. . . AND LOWERS EXHAUST TEMPERATURES

BECAUSE pressure raises the temperature inside cylinders before ignition, it is a commonly accepted idea that high compression engines present a heat problem.

Such is not the case. The waste heat of a high compression engine is less than that of a similar engine of lower compression ratio.

Obviously this is so, since when an equal amount of fuel is burned in each type, the higher compression motor converts a greater percentage of the fuel energy to power, leaving less heat to be dissipated through cooling systems and exhaust.*

These conclusions of theory are borne out by experimental practice. During several years the experiments made in Ethyl Engineering Laboratories have indicated this result, and data are now available from a series of tests which illustrate the point conclusively.

The accompanying graphs are made from tests of a typical eight cylinder engine.

In Figure 1 the power of the engine is plotted with the use of three different heads to give compression ratios of 5.2 to 1, 6.0 to 1, and 7.0 to 1 (having compression pressures of 104 pounds, 130 pounds, 171 pounds, respectively). The differences in the percentage of power increases at different speeds are due largely to the use of planed heads to secure higher compression and do not exist if combustion chambers are correctly proportioned.

Figures 2 and 3 present the lower heat losses resulting from a more efficient use of energy. The cooler temperatures which the higher compression ratios maintain at given r.p.m. (because of their higher power output) become increasingly important as speed increases. The lower exhaust gas temperatures which accompany high compression ratios are of importance both because of the lower temperatures imposed on the exhaust valves and because of the smaller amount of heat transmitted from the exhaust pipe to the driving compartment during hot weather.

Body-designing engineers will also find the curves in Figure 3 par-

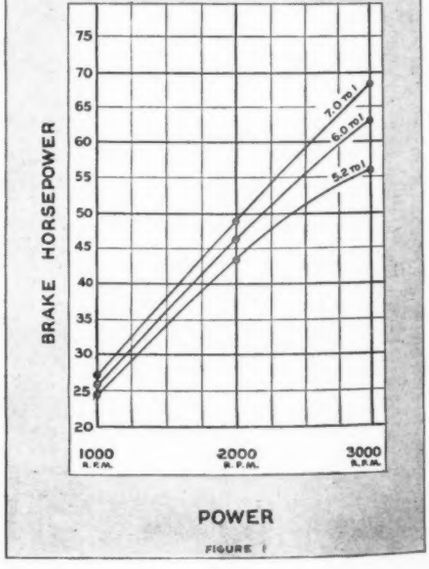
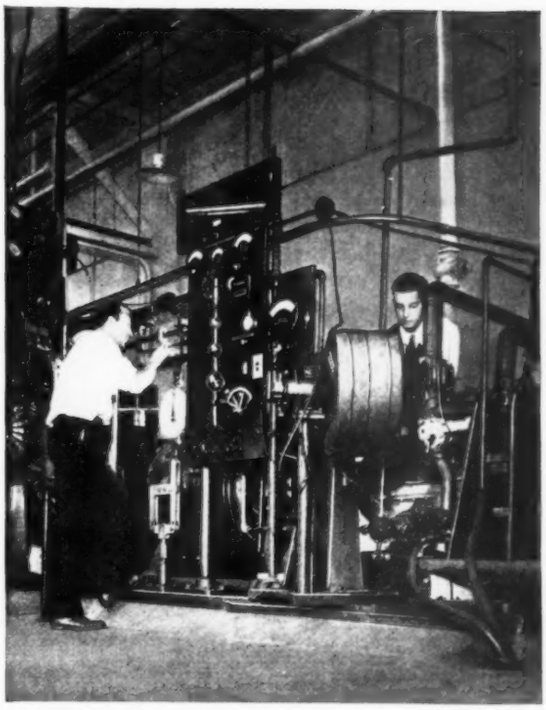


FIGURE 1

*This assumes the use of fuel of sufficient anti-knock value to prevent detonation in each engine.



In this heat balance experiment, the temperature of exhaust gases is measured by a thermocouple pyrometer. The amount of heat absorbed by cooling water is measured by sensitive thermometers which indicate the temperature of the water upon entering and leaving the cooling jacket, and by scales which weigh the amount of water passing through. The torque is measured by an electric dynamometer. The speed is measured by an electrically operated revolution counter and a stop watch.

ticularly attractive. Higher compression pressures hold a promise for them of radiators of smaller area even with motors of increased power. This will be of even greater importance in aviation, where air resistance of the frontal area has a marked effect on performance.

A large number of high compression cars are now on the road. These cars operate without detonation on the Ethyl Gasoline commercially available on every highway in the country, and their performance is far superior to that of cars having the usual average compression.

A manufacturer who desires the increased efficiency of high compression motors but distrusts the available supply of a fuel which will operate without detonation is running from a shadow. There are now over 250,000 pumps in the country that bear the Ethyl emblem. Approximately five million motorists already use Ethyl Gasoline regularly, and the number is growing rapidly.

With the public demanding more power, faster acceleration and favoring low sales prices, the compression pressures of 1932 models seem certain to be higher. And if the present success of cars developing superior performance is an indication, those manufacturers who take best advantage of the compression pressures permissible with Ethyl Gasoline will be rewarded by increased sales. Ethyl Gasoline Corporation, Chrysler Building, New York City.

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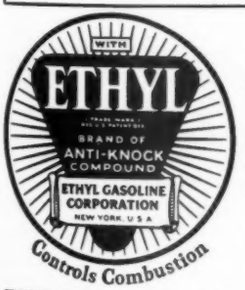
ETHYL GASOLINE

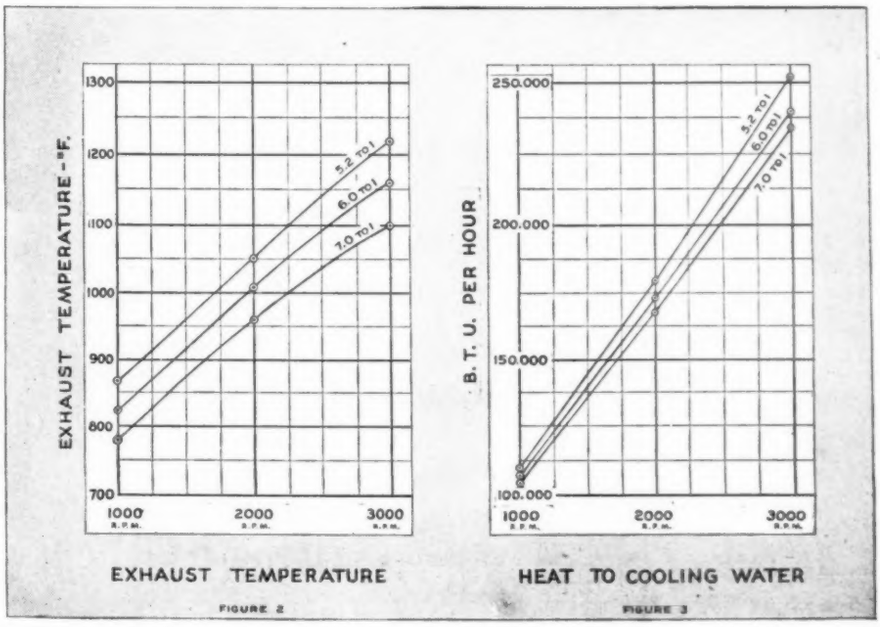
The active ingredient used in Ethyl fluid is lead

FIGURE 1 shows the relative brake horsepower of the engine (at three ratios of compression) for speeds between 1000 and 3000 r.p.m. Figure 2 shows the temperatures of exhaust gases in degrees Fahrenheit taken by a thermocouple in the exhaust pipe. Figure 3 shows the amount of heat absorbed by cooling water in British Thermal Units per hour.



The Ethyl emblem on any pump stands for tested gasoline of Ethyl quality. Constant inspection of gasoline taken from Ethyl pumps throughout the country guards this standard. Ethyl Gasoline is always colored red.

THE DRIVER OF ANY CAR ANYWHERE IS NEVER FAR FROM ETHYL GASOLINE



When writing ETHYL GASOLINE CORPORATION *please mention The Petroleum Engineer*

vapor or liquid lines are absolutely clear of oil or vapors before the work is started. When lines are to be disconnected and there is a possibility of vapor or liquid in these lines, arrangements are made to catch the liquid rather than to let it spill on the ground, later to vaporize and drift around the refinery as a combustible mixture. To illustrate the value of such precaution, the following accident is described: A crew of men disconnected the vapor line from a still; a small quantity of condensate spilled out of the line when the connection was broken. The crew gave this spill no further thought until several minutes later when the liquid had vaporized and drifted with the air over 100 feet to a fire in the fire box of another still. A flash occurred and, according to those observing it, seemed to follow in a sheet of light blue flame back to the source of the spill. A part of the crew succeeded in escaping the flash, but two men were so severely burned that they died.

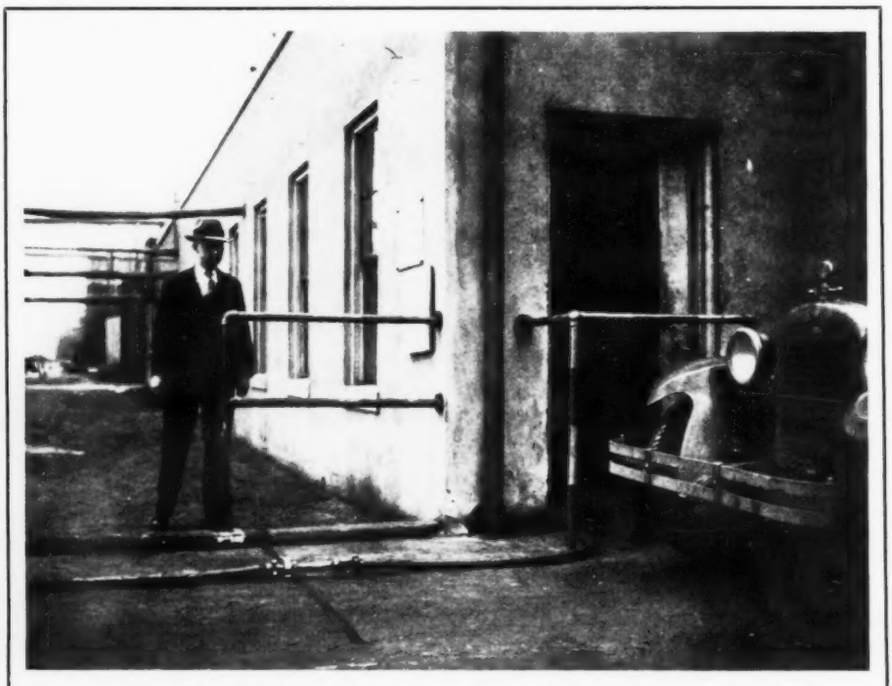
An electric lighter provided so refinery workers may light their smokes as they leave the plant.

Much is being accomplished through committee work and by encouraging workers in the plant to express their ideas and make suggestions for improvement of equipment or operations. Some companies are compensating employees for ideas submitted which prove of real value to the company. Even experienced workmen have learned that further study, brought about by conferences in meetings and committees, reveals much about their own work that they had not suspected.

Executives are very much in agreement that complete information and understanding by workers of the work they are doing serve to eliminate mistakes, consequently, eliminating accidents. Some companies have developed instruction books within their own organizations which give employees limited information on how to handle their work so as to prevent accidents. Workers are instructed in rendering first aid to the injured. This causes them to be more thoughtful about the prevention of injuries. Many lives are saved each year by the application of artificial respiration to workers who have been overcome by petroleum vapors or hydrogen sulphide gas. In some refineries every employee knows how to perform artificial respiration.

Companies are also holding fire drills, providing employees with fire problems and putting gangs through the actual steps of fighting an imaginary fire. Each employee in the fire zone of the plant does just what he would do in case of an actual fire. Some report to the fire chief, others move the fire equipment into position, others take up their stations at pumps, others close gates on lines which might provide fuel for the fire, and still others attend to switching water lines and foam generator lines so as to deliver a predetermined quantity of extinguishing material at the point of the fire. It has been noticeable in the plants where such training has been carried on that the workers are more alert to fire prevention and that fires do not frequently occur.

The old instruction to employees to "keep cool in case of fire," has become obsolete. Men instructed so that they know what to do in case of fire proceed to do as they have learned. Men who do not know what to do are the ones who actually lose their heads under these conditions.



Here, it is impossible to step past the corner of the building or out of the open door in the path of an automobile.

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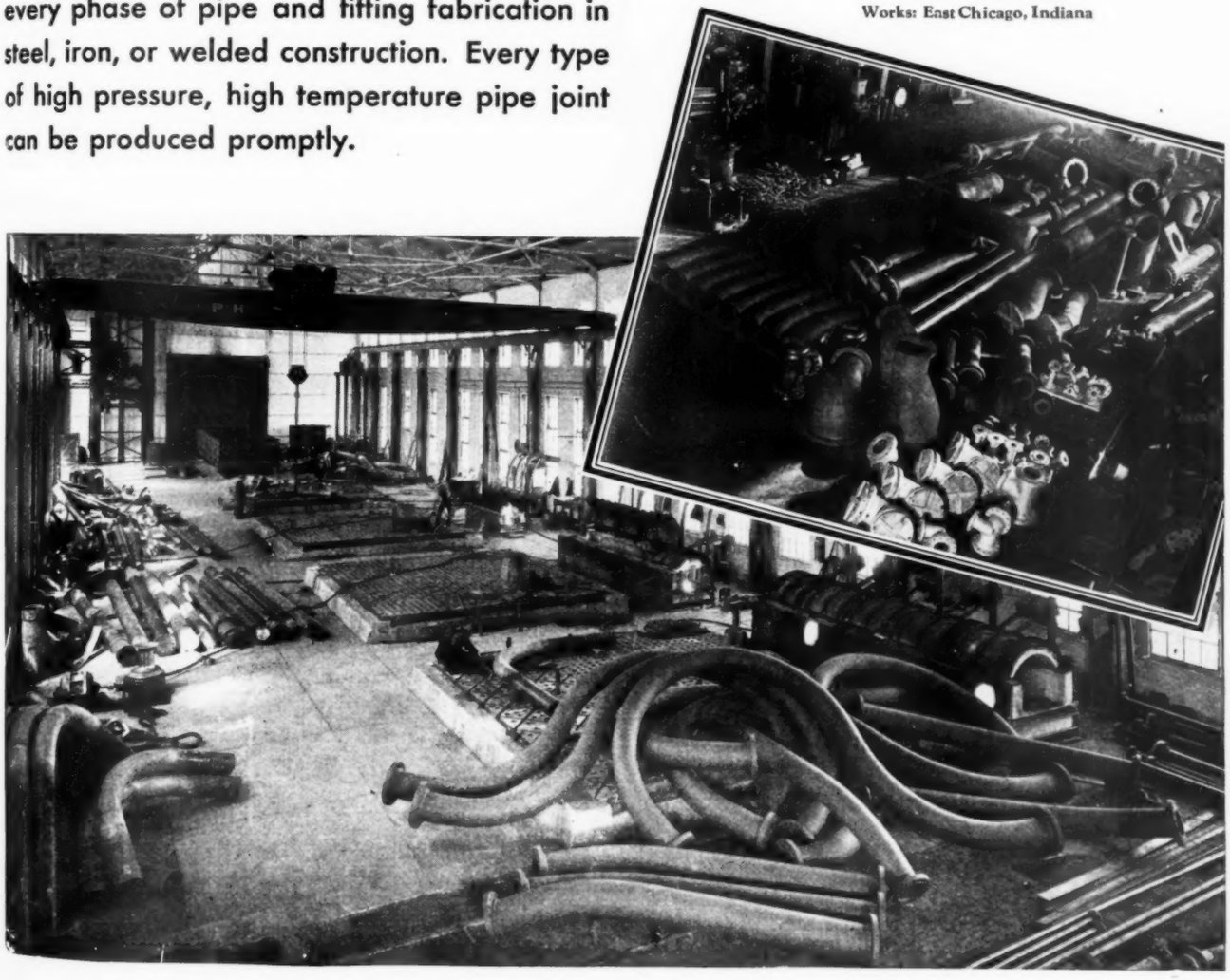

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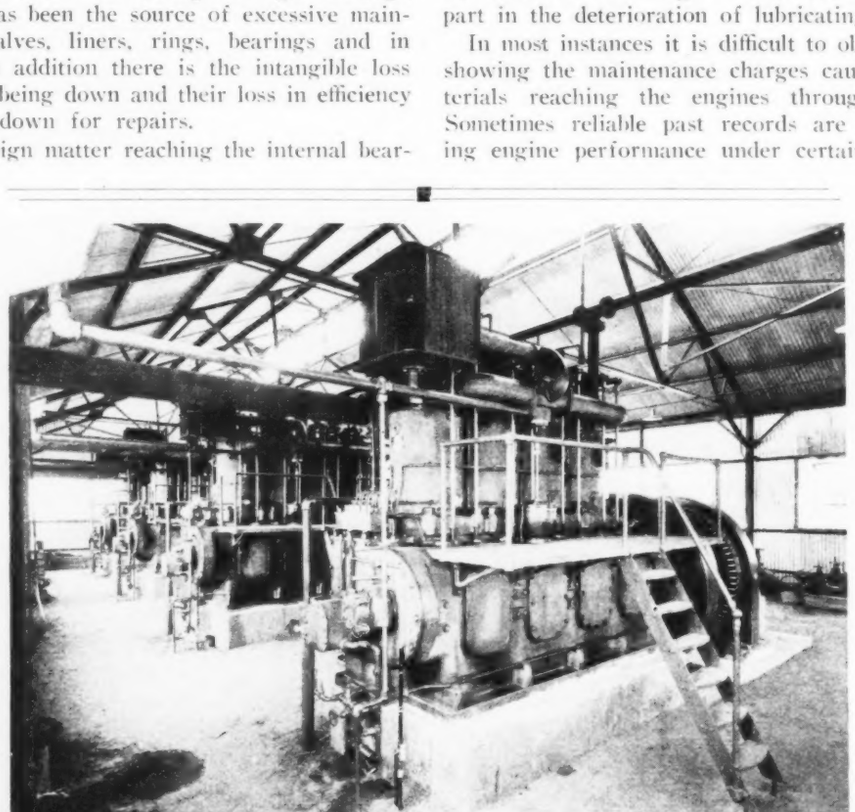
Air Filters Prove Beneficial

ENTRY of sand and other abrasive material to internal combustion engines in pipe line stations through air intake lines is a phase of station operation that frequently is given too little consideration. In a great many instances the geographical location of the station minimizes the problem. At other sites dirt entering the engine through the air intake line has been the source of excessive maintenance costs on valves, liners, rings, bearings and in lubrication costs. In addition there is the intangible loss resulting from units being down and their loss in efficiency prior to being shut down for repairs.

Prevention of foreign matter reaching the internal bearing surfaces of the engine appears more imperative when it is considered that recent tests show from one to 4.23 grains of dust in every 1,000 cubic feet of air. The test was made in industrial districts where conditions were considered fair.



Interior of an air lift plant in Oklahoma, showing position of air filters.

As many pipe line stations are located close to highways, railroads, industrial sites or in a sandy or windy country the dust problem is, of course, greater. Stations so located invariably show greater maintenance costs except in stations where provisions are made to prevent the abrasive material reaching the engine.

Although engines of different design and size take different quantities of air, the ratio of dirt to the total quantity of air under similar conditions is the same. As an example, consider a four-cylinder 400 h.p. at 200 r.p.m. four-cycle, 17 by 24 air injection engine. Assuming the unit to be operating under conditions where the air contained 4.23 grains of dirt per 1,000 cubic feet. The working cylinders have a volumetric capacity of 1,261 cubic feet of free air per minute. Add an approximate total of 10 per cent for the compressor and the total will be brought to 1,387 cubic feet of air per minute. At this rate 5.87 grains of dust per minute would be going to the engine through the intake line, most of which is carried off by the lubricating oil.

Over a full 24 hour run 8,452 grains of dust, or 1.21 pounds, would reach the engine. Over a period of 300 days the total would swell to 363 pounds of dust. Most of this foreign material is carried away by the crank case oil and is removed from the oil either by filters or centrifuges. Some of it is deposited on the piston head and is frequently mistaken for carbon. However, before it is removed from the engine it accelerates wear and plays a part in the deterioration of lubricating oil.

In most instances it is difficult to obtain concrete figures showing the maintenance charges caused by abrasive materials reaching the engines through air intake lines. Sometimes reliable past records are not available showing engine performance under certain conditions. Again operating conditions vary widely. Where conditions have permitted a desirable analysis the results have been surprising.

Such a case may be found in a gas compressor station in Oklahoma where an accurate record of valve maintenance was available for a period of 11 years. Six of these years represented the time the station was operated without air filters and the remainder was for the period it was operated with filters. During the entire period the station operated on an average of 168 days per year. Following installation of filters on the air intake lines maintenance charges on mixing, exhaust and intake valves were not only lowered 34 per cent but lubrication costs were reduced 25 per cent. This does not take into account the loss in efficiency of the units or the down time of the engines.

This station equipment consists of eight 190 h. p. units with one 110 h. p. and one 70 h. p. compressor used as reserve compressors. The station is located on a hill adjacent to a paved highway and a railroad with a cinder roadbed. In addition the soil in the territory is sandy and is whipped into swirls by the frequent sand storms.

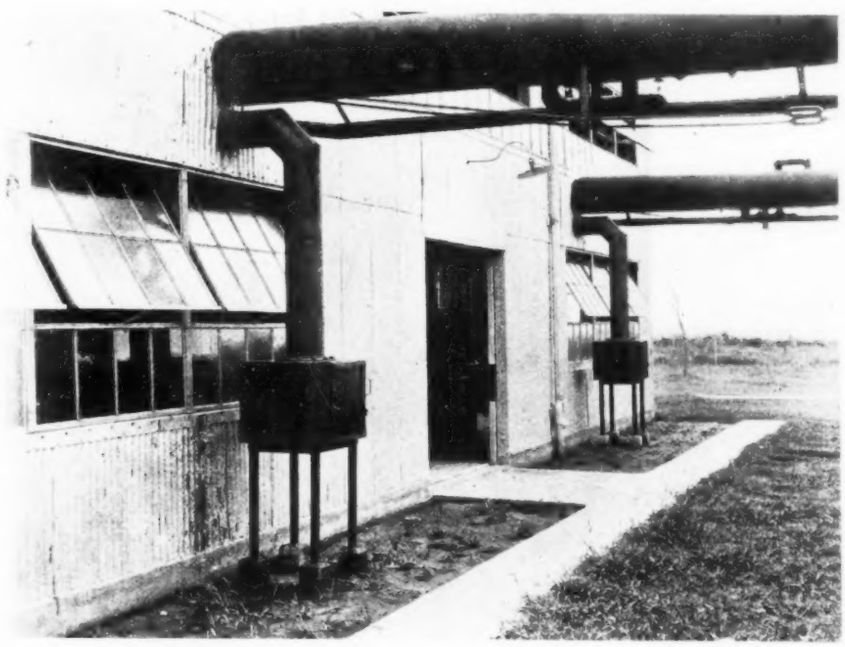
Originally the air intake lines were located inside the station structural steel and sheet metal buildings. Six years later the lines were moved outside and at the time of the change air filters were installed. During this six-year period liner and piston wear was rapid as was valve wear.

to Pipe Line Station Operation

Mixing valve trouble was particularly noticeable and expensive. Such valves were badly cut and worn by the sand and grit carried in by the air flowing through them. It was the practice to leave them in service until they became unfit for use. When removed they were repaired by building them up by welding and then machining them to size.

Over the six-year period the maintenance for mixing valves alone averaged slightly under $100 annually. This included the 10 new valves purchased in six years, the repair of worn and damaged valves and the labor charges. When the filters were installed on the intake lines the maintenance charge on mixing valves was lowered 51 per cent.

By far the greater amount of the maintenance cost went for replacing and repairing exhaust valves. Prior to filtering air each engine was charged with three new valves annually and their cost was above $800. This, of course, entailed the expense of new seats and labor charges. This, along with the removal and repair of valves and seats three times annually, caused the maintenance charge on exhaust valves to soar to slightly under $1,500 annually.



Air filters on the Prairie Pipe Line Co.'s station at Blair, Okla.

After the installation of the filter the exhaust valve maintenance charge was reduced 33 per cent, effecting a savings of almost $500 annually over the previous period. During the last five years each engine has required two sets of valves and seats annually and two grinding jobs, which accounts for the material savings in repair and labor.

The annual maintenance cost on the intake valves was considerably under that of exhaust valves because the intake valves cost approximately half that of exhaust valves and their wear was much longer. However, the annual savings from this source was better than 31 per cent of the cost for intake valve repair prior to the installation of air filters.

During the six-year period an average of five new intake valves were installed annually. The intake valves on each machine, however, were ground three times a year. Under present conditions these valves are ground twice a year on all units.

When considering all three types of valves a savings of approximately $600 is effected annually since the installation of the air filters on the intake lines. This represents only the direct tangible savings and not such indirect charges as loss of efficiency and loss as a result of the units being down.

The paring of maintenance charges at this station is accomplished at a filter cost of approximately $140 annually, including interest on the investment and depreciation. Depreciation of equipment is spread over a period of 10 years and the only added equipment necessary is a cleaning tank, the cost of which is slight.

Another savings noted at this station following the installation of the filters was in the lubricating costs. Before installation of filters an eight drop sight feed was used and the engines consumed about 1,260 gallons of oil annually.

During the past five years the engines have been lubricated on a six drop sight feed and the annual total consumption of oil is down to less than 950 gallons. This is attributed mostly to the smoother engine performance and slower liner and ring wear as a result of cleaner air being introduced into the engine. Assuming the cost of the lubricating oil to be .50 per gallon, a lubrication cost saving of about $160 annually is effected.

Detailed figures on costs before and after installation of filters at oil line stations using Diesels as prime movers are not available. However, such a station on a line coming out of the Texas Panhandle showed surprising reductions in lubricating oil consumption during the first six months following installation of air filters on the intake line. This station is located in a sandy country where sand storms are a daily occurrence.

The engines were burning purchased fuel centrifuged at the station and liner wear was more rapid than average while lubricating oil consumption was considerably above that of other stations with identical equipment but in more favorable locations so far as dust problems are concerned.

After six months of operation with filters the engines had a much lower record of lubricating oil consumption and operating conditions as a whole improved.

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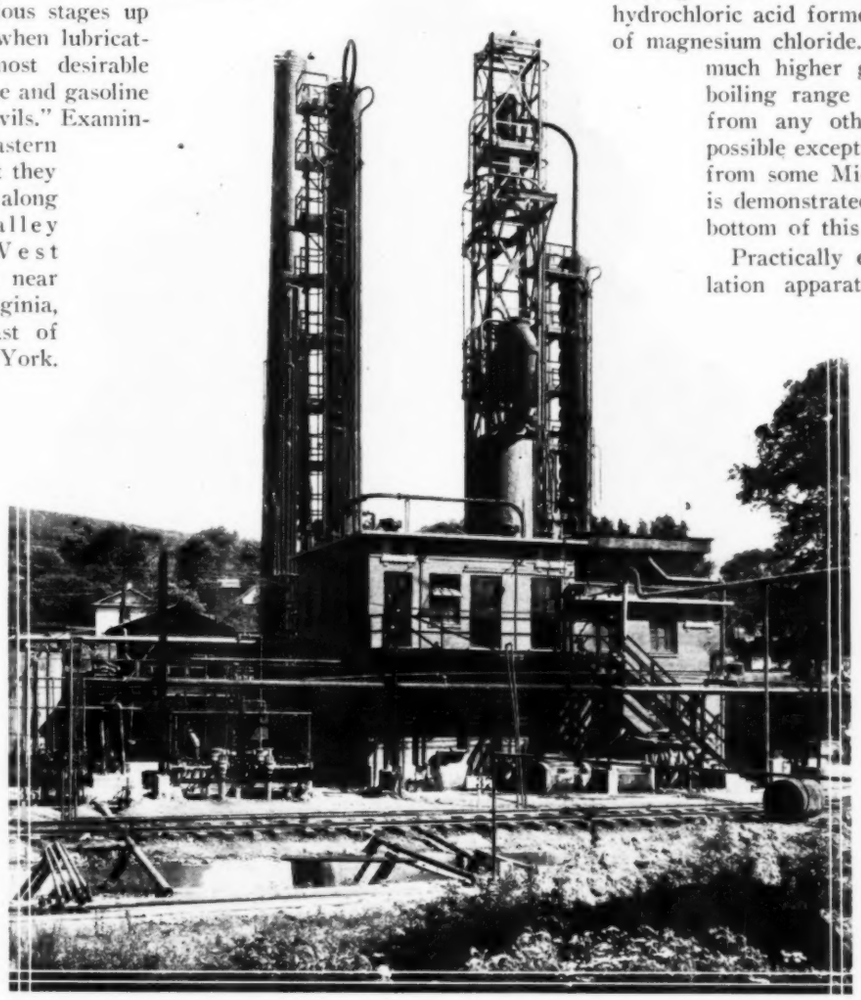
Developments in

Refining Pennsylvania Crude Oil

By C. M. RIDGWAY, *Supt. Old Dutch Refining Co.*

NEARLY every member of the oil fraternity is familiar with the history of the Pennsylvania oil field, the birthplace of the industry and the training school of many men now holding executive positions in the production and refining divisions of oil companies the world over. Many of these men have been connected with the industry practically from its very inception. They have followed the processing of this crude from the time when kerosene was the most valuable product, through its various stages up to the present time when lubricating oils are the most desirable products and kerosene and gasoline are only "necessary evils." Examination of a map of eastern fields will reveal that they extend due northeast along the Ohio River valley from Huntington, West Virginia, to a point near Wheeling, West Virginia, thence somewhat east of north to Olean, New York. Nearly all of the production is located east of this line, although considerable crude is obtained from the Ohio fields as far west and north as the vicinity of Youngstown.



It will be noted that the various crude oil purchasing agencies post prices covering several grades. These grades are named either for the district in which the crude is produced or the pipe line serving that district, viz.: Bradford — produced in the Bradford; Eureka — from the Eureka Pipe Line Company serving part of West Virginia; Buckeye — oil collected by the Buckeye Pipe Line which serves the Ohio fields.

The crude produced in this district as a whole is recognized as being the highest quality base obtainable for the production of lubricants. It is practically uniform in quality, the average gravity being about 43 degrees A. P. I. However, a few freaks are encountered, such as a 32-degree A. P. I. crude found near Franklin, Pennsylvania, and a 50-degree A. P. I. crude produced near Falling Rock, West Virginia. The only essential difference between the grades is the gasoline and kerosene content. The lubricants produced from any of these grades using the same methods will be identical to all practical intents and purposes, although the lubricating stocks from some crudes will require more drastic filtering than others.

The crude is a sweet, distinctly paraffin base oil which does not present any unusual problems, although some trouble is encountered with hydrochloric acid formed by the hydrolysis of magnesium chloride. All cuts possess a much higher gravity for a given boiling range than those obtained from any other crude, with the possible exception of the light ends from some Michigan crudes. This is demonstrated by the table at the bottom of this page.

Practically every type of distillation apparatus, such as cheese box stills, cylindrical batch stills, continuous batteries, single flash steam atmospheric pipe stills, shell stills operating under vacuum and vacuum pipe stills has been used in processing the oil.

Lubricants of good quality can be produced by any one of these methods which speaks well for the inherent characteristics of the oil. However, the desire for increased yields and better physical characteristics has prompted the installation of many pipe still units of the steam-atmospheric and vacuum types.

In many plants the conventional steam atmospheric pipe still is used. While in other plants the crude is topped down through gas oil in a similar still and then transferred to a vacuum pipe still. The usual method of operation in the

Average Boiling Point	Penna.	Mid-Cont.	Gulf Coast
	A. P. I. Gravity		
300° F.	54.7	53.5	46.5
400° F.	50.6	44.3	37.0
500° F.	44.0	39.0	29.0

latter case is to take off the wax distillate as an overhead cut and the long residuum or desired grade of stock from the bottom of the tower. The vacuum tower is equipped so that side-drawn steams can be taken when it is desired to make a steam refined stock of superior characteristics as an overhead product of a very high flash and viscosity stock such as 630 degrees F. flash steam refined as a bottoms product. A number of articles have been published dealing with these types of apparatus.

Two rather distinct methods of handling the crude prevail in this district. In one a 90 viscosity at 210 degrees F. long residuum is used for a blending base for motor oils and in the other a 150 viscosity at 210 degrees F. bright stock is prepared for the base. Other types of steam refined stock are made and will be discussed in another paragraph.

Where a steam atmospheric pipe still is used, the following yields may be expected when running to long residuum:

Product	Yield	A.P.I.	Initial	End Point	Flash	Fire	Viscosity
Light Gasoline	25.3	68.0	100	365	.....	.....	.....
Naphtha	5.6	52.8	315	416	110	.....	.....
Kerosene	19.8	45.6	420	565	160	.....	.....
Gas Oil	10.6	39.4	525	700	.....	.....	.....
Wax Distillate	12.0	36.2	.....	.....	360	400	60 @ 100° F.
Long Residuum	25.7	28.5	.....	.....	505	555	90 @ 210° F.
Loss	1.0						

In the event that 145 viscosity stock is desired the yields down through and including gas oil will be identical with those given above, but the wax distillate and stock yields will be approximately as follows:

Product	Yield	A.P.I.	Flash	Fire	Viscosity
Wax Distillate	20.1	35.0	360	405	85 @ 100° F.
145 Vis. Stock	17.6	27.9	570	630	145 @ 210° F.

For many years Pennsylvania gasoline was considered a premium product due to its appearance, odor, freedom from sulphur and high gravity. However, since the advent of the high compression motor it has lost favor due to its tendency to "knock" in engines of this design, particularly those gasolines having a high end point. At the present time the gasoline is cut with an end point of about 360 to 380 degrees F. and blended with either cracked gasoline or those motor fuels which have an inherently high benzol equivalent. A good grade of motor gasoline is produced by this method since the low end point Pennsylvania gasoline possesses a fairly good benzol equivalent.

Pennsylvania kerosenes are marketed in three grades: 45, 46 and 47 degrees A. P. I. They are of excellent quality, water white, good odor and have unexcelled burning properties. As a matter of fact these kerosenes are used as a basis of comparison for the performance of kerosene made from other crudes. They only require a very slight acid treat and in some cases a mild doctor treat to make them marketable.

The gas oil fraction is often sold as such or is used as a high-grade fuel oil. Recently the tendency has been to crack this stock for gasoline and blend a low end point, straight-run gasoline with it for the production of a premium motor fuel.

The wax distillate is dewaxed in the conventional manner by chilling in continuous chillers and pressing at a temperature 15 to 20 degrees below the cold test desired in the finished neutral. The average cold test of these neutrals is approximately plus 25 degrees F., hence the pressing temperature is approximately plus 10 degrees F. Where zero cold test neutrals are desired, the wax distillate is usually pressed at plus 35 degrees F., and again at minus 15 degrees F. When pressing at normal temperatures the rate is in the neighborhood of ½ barrel per 48-inch plate per 24 hours.

The dewaxed distillate or pressed distillate as it is known in this field is reduced by distillation to the desired neutrals. Many of the plants are equipped with pipe stills which are used for this service and reducing centrifuge solution. The results obtained by the distillation of a pressed distillate in such a unit follow:

Product	Yield, Per Cent	A.P.I.	Viscosity	Flash	Fire
Overhead	31.2	37.5	.....	.....	.....
Side Stream	9.2	33.5	77	360	410
Bottoms	59.0	32.0	140	410	465
Loss	0.6	.....	.....	.....	.....
Charge	100.0	35.0	79	.....	.....

A few plants rerun the overhead gas oil from this unit in the same apparatus and produce such products as miner's neutral or 300 oil, a high flash, long burning oil. The yields from such a run are indicated below:

Product	Yield, Per Cent	A.P.I.	Viscosity @ 100° F.	Flash	Fire
Overhead—Gas Oil	55.8	45.3	.....	.....	.....
Side Stream—300 Oil	22.4	36.5	50	300	360
Bottoms—Neutral	21.3	35.4	60	340	390
Loss	0.5	.....	.....	.....	.....
Charge	100.0	38.1	45	.....	.....

After distillation the neutrals are filtered through Fuller's earth to remove moisture and to obtain the desired color. It is interesting to note that none of the lubricating cuts are treated with acid, but are filtered to the desired color.

The wax resulting from pressing wax distillate is melted and pumped to the wax sweaters where it is transferred to the sweating pans. The molten wax is chilled until it solidifies and is then gently warmed at a predetermined rate and the oil known as foots oil, which was entrained with the wax, drains away. The foots oil usually takes one of two courses. It may be added to the pressed oil and rerun, or it may be added to the wax distillate. The final sweating temperature is determined by the required melting point of the wax. The wax remaining after this operation can be cut into various grades by resweating. After sweating the wax is melted and filtered through Fuller's earth or bone black. It is then prepared for shipment by either chipping or molding into cakes. The finished white scale wax usually amounts to about 1.3 per cent on the crude by volume.

The steam refined stock resulting from the primary distillation is sold as such or is dewaxed and sold as bright stock. In the preparation of bright stock, the steam refined material is filtered, either hot or diluted with naphtha, to the desired color, the filtering loss amounting to about 5 per cent of the net stock. After filtration the stock is diluted in the ratio of about 60 parts of naphtha to 40 parts stock and dewaxed by either cold settling or centrifuging.

Where cold settling is used it is heated to approximately 90 degrees F., and then transferred to a coiled insulated tank and the temperature decreased very gradually to a point approximately 40 degrees F. below the desired cold test of the finished oil. The mass is allowed to stand for approximately 24 hours; during which time the petrolatum mixture settles to the botttom due to the difference in specific gravity between it and the solution. This difference in specific gravity is brought about by the fact that the petrolatum crystalized with a naphtha content of approximately 40 per cent, whereas the oil-naphtha mixture con-

tains 60 per cent naphtha. After settling, the total time for chilling, etc., requiring 4 to 6 days, the naphtha-oil solution is carefully pumped off and the petrolatum removed from the tank. About the lowest practical cold test obtainable by this method is plus 35 degrees F. The petrolatum loss amounts to 15 to 28 per cent. The petrolatum mixture which contains some oil is carefully steam distilled and the petrolatum which is left in the still further treated and filtered. It is graded into various classes by the finished color, which ranges from red to lily white, depending upon the thoroughness of decolorizing.

The majority of the refiners use a continuous chilling method and dewax with centrifuges. Where low cold test stocks such as zero to plus 5 degrees F. are desired the naphtha-oil ratio is increased to 75:25 and the oil chilled to about minus 50 degrees F., the actual centrifuging taking place at about minus 40 to 45 degrees F. When a high melting point petrolatum is desired, the raw petrolatum is rediluted and centrifuged a second time. It is then handled in the manner outlined in the preceding paragraph. Where normal cold tests of plus 25 to plus 35 degrees F. are made the petrolatum loss will amount to about 12 per cent of the net stock processed. The loss increases of course with decreasing cold test and may amount to as much as 25 per cent where zero cold test stocks are produced.

The bright stock solution is reduced either in shell stills by fire and steam or in pipe stills. After reducing it is filtered to brighten and give final color.

The fact that this crude yields lubricating oils of superior quality is apparent when the following physical characteristics are considered:

Neutrals

Pennsylvania neutrals have a classification peculiar to this field, being unlike that of any other district. They are sold as follows:

36 Miner's Neutral: A 36-degree A. P. I.—300-degree F. flash, long burning oil. Also known as mineral seal.

34 Neutral: A 34-degree A. P. I. oil with a viscosity of approximately 60 sec. at 100 degrees F. Saybolt Universal.

34 Sundebloom: Regular 34 neutral sun bleached to impart a rose bloom.

150 Neutral, 180 Neutral, 200 Neutral, 220 Neutral: These neutrals are usually sold with a 3 N. P. A. color. The numerical classification refers to the Saybolt Universal viscosity at 70 degrees F.

The physical characteristics of some of these neutrals follow:

A. P. I.	34.0	33.7	31.7	31.5	31.0	30.5	39.5
Flash	340	350	400	410	425	430	445
Fire	390	400	460	470	480	485	500
Viscosity @ 70° F.	.....	83	145	163	205	230	375
Viscosity @ 100° F.	60	75	130	145	185	200	330
Viscosity @ 130° F.	.....	53	75	81	97	103	.....
Viscosity @ 210° F.	.....	.....	42	43	45	47	.....
Cloud	.....	.....	.....	40	40	40	.....
Pour	30	30	25	25	25	25	.....
N. P. A. Color	1½	1½	3	3	3	3	.....
Carbon Residue	.10	.12	.18	.20	.21	.22	.....

Steam Refined Stocks

Grade	Long Residuum	600 Fire	635 Fire	650 Fire	600 Flash	630 Flash
A. P. I.	28.5	27.5	26.5	26	25.5	22.0
Flash, Degrees F.	490	540	575	590	600	630
Fire, Degrees F.	540	615	645	670	680	710
Viscosity @ 210° F.	90	145	170	190	250	280
Pour	75	60	60	65	70	80
Carbon Residue	1.25	2.75	3.25	3.5	4.0	4.5

Bright Stocks

Grade	Long Residuum	150 Viscosity
A. P. I.	29.0	28.0
Flash, Degrees F.	490	545
Fire, Degrees F.	540	610
Viscosity @ 100 Degrees F.	980	2077
Viscosity @ 130 Degrees F.	400	845
Viscosity @ 210 Degrees F.	90	150
Pour	25	30
N. P. A. Color	6	8+
Carbon Residue	.75	1.31

Motor Oils

At least four distinct methods of preparing motor oils are in use in this district. These methods are outlined below:

1. Blending 410-degree F. flash neutral with 150 viscosity bright stock.
2. Blending 410-degree F. flash neutral with 90 viscosity at 210-degree F. bright stock.
3. Still blend pressed distillate or neutral with 90 viscosity bright stock and top off to the desired viscosity.
4. Still blend pressed distillate or neutral with 150 viscosity bright stock and top off to the desired viscosity.

The physical properties of a series of motor oils obtained by method No. 1 are given below:

	GRADE					
	Light	Medium	Medium Heavy	Heavy	Special Heavy	Extra Heavy
S. A. E. No.	20	30	40	50	60	60+
A. P. I.	29.5	29	28.5	28	27.5	27
Flash	435	450	460	475	510	525
Fire	500	515	520	545	585	595
Viscosity @ 100° F.	224	415	638	914	1620	.....
Viscosity @ 130° F.	135	202	286	400	575	625
Viscosity @ 210° F.	50	60	70	85	110	125
Pour	30	30	35	35	40	45
Color	4	6	6+	6+	7	7+
Carbon Residue	.35	.46	.50	.84	.96	1.15

The final yields of a crude processed in the manner outlined in this article would approximate the following:

Gasoline, 365 E. P.	25.3%
Naphtha, 315 IBP-415 E. P.	5.6
Kerosene, 46 Gravity	19.7
Gas Oil	31.7
300 Oil	1.2
34 Neutral	1.2
150 Neutral	1.7
180 Neutral	9.6
Bright Stock	13.7
Crude Scale Wax	1.3
Petrolatum	2.4
Loss	4.6
Total	100.0%

PIPE LINES UNDER CONSTRUCTION AND CONTEMPLATED FOR 1931

Type Line	Company Name	Headquarters	Initial Station	Terminal	Size Pipe	Length in Miles	Remarks
G. L.	Associated Oil Co.	San Francisco, Calif.	Mid-State Fields	Tidewater	6"	60	Reconditioning 90-mile screw line and building 60 miles new line for gasoline carrier.
O. L.	Arkansas Fuel Oil Co.	Shreveport, La.	East Texas	Shreveport, La.	8"	70	Under construction.
G. L.	Arkansas Valley Gas Co.	Ft. Smith, Ark.	Ft. Smith		10"	80	Propose extension to cities south of Ft. Smith.
G. L.	Billings Gas Co.	Billings, Mont.	Dry Creek	Billings		120	Est. cost $2,500,000. Bozeman western terminal. Line to go to Helena and Butte later.
G. L.	Capital Gas Co.	Billings, Mont.	Eastern Montana	Winnipeg, Canada		400	Proposed.
G. L.	Central Montana Utilities Co.	Minneapolis, Minn.	Great Falls, Mont.	Lewiston, Mont.	8"	100	Proposed.
G. L.	Central Public Service Corp.	Chicago, Ill.	Kentucky	Muncie, Ind.	18"	260	Const. work by Central Nat. Gas Corp. Proposed.
G. L.	Colorado Nat. Gas Co.	Colorado Springs, Colo.	Stevens, Kans.	Colo. Sprgs.	12"	210	Proposed.
G. L.	Columbia Gas & Elec. Co.	New York, N. Y.	W. Vir.	Detroit	24 & 22"	300	Two river crossings in; no further work.
G. L.	Dominion G. & E. Corp.	New York, N. Y.	Turner Valley				Proposed to build to cities in Alberta and Sask., Canada.
G. L.	Gulf P. L. Co.	Pittsburgh, Pa.	Columbia, S. A.	Tidewater			Contemplating $25,000,000 South American pipe line project.
G. L.	Jerome Drumheller	Spokane, Wash.	Cut Bank, Wyo.	Seattle	20"	500	Proposed.
O. L.	Empire P. L. Co.	Bartlesville, Okla.	Oklahoma City Field	Houston, Tex.	10"	475	Proposed. Surveyed last year.
O. L.	Getty, Geo. F., Inc.	San Francisco, Calif.	Kettleman Hills	Tidewater		100	To be completed July 31, 1931.
G. L.	Great Lakes P. L. Co.	Ponca City, Okla.	Extend to Duluth		4"	150	Under consideration.
G. L.	Kentucky Natural Gas Corp.	Owensboro, Ky.	Evansville, Ind.	Terre Haute, Ind.	12"	110	Connor & Son, Contractors. Under construction.
G. L.	Public Service Co. of Nebr.		Texas Panhandle	Colo. & Nebr.	18"		Making property survey. Est. cost $7,500,000.
G. L.	Magnolia P. L. Co.	Dallas, Texas	East Providence, R. I.	Springfield, Mass.	6"	100	Under construction.
O. L.	Mexican Eagle Oil Co.	New York, N. Y.	Vera Cruz	Mexico City	10"	142	Under construction.
G. L.	Mississippi Industrial Gas Co.	Jackson, Miss.	Jackson Field	Terry, Miss., etc.	6"	140	Under construction.
G. L.	Minnesota Northern Power Co.	Minneapolis, Minn.	Williston, N. D.	Regina, Sask., Can.	12"	115	Proposed.
G. L.	Montana Power Co.	Butte, Mont.	Wyoming	Butte & Anaconda			Est. cost $13,000,000.
G. L.	Memphis Nat. Gas Co.	Memphis, Tenn.	Extension of mains to W. Tenn.		12"		Under consideration.
G. L.	Montana-Dakota Pw. Co.	Minneapolis, Minn.	Williston, N. D.	Minot, N. D.	12"	125	Making franchise surveys.
G. L.	Mo.-Kan. P. L. Co.	Chicago, Ill.	Jackson, Miss.	N. to present trunk line			Rumored.
G. L.	North Central Gas Co.	Casper, Wyo.	Cut Bank, Wyo.	Bridgeport, Nebr.	14-12-10-8"	388	Project held in abeyance.
G. L.	Okla. Nat. Gas Corp.	Tulsa, Okla.	Big Lake, Texas	San Angelo	12"	74	Twenty per cent complete.
G. L.	Pacific Gas & Elec. Co.	San Francisco, Calif.	Sacramento, Calif.	Seattle, Wash.		500	Considering extensions to Oregon and Washington, also Kettleman Hills to Fresno.
O. L.	Sinclair P. L. Co. of Tex.	Tulsa, Okla.	East Texas	Houston	12"	250	Rumored.
G. L.	So. Saskatchewan Gas, Ltd.	Montreal, Canada	Bowdoin, Mont.	Regina, Canada		175	Proposed. Nesbitt, Thomson & Co. project.
O. L.	Stanolind P. L. Co.	Tulsa, Okla.	Carrollton, Mo.	Wood River, Ill.	8"	240	Rumored.
G. L.	Tri-Cities Utilities, Ltd.	Regina, Saskatchewan, Canada	Kinsella Area, Canada	Regina, Sask.	24"	357	Est. cost $25,000,000; C. O. Moore Co. project; Ford, Bacon & Davis, engineers.
G. L.	Tennessee Nat. Gas Corp.	Chattanooga, Tenn.	Sunbright, Ky.	Chattanooga		160	Est. cost $2,000,000; contract to Gas Power Corp., 75 Broad St., New York.
O. L.	Illinois P. L. Co.	Findlay, Ohio	Yates, Tex.	Glenn Pool, Okla.	10"		Rumored.
G. L.	Wasatch Gas Co.	Salt Lake City, Utah					Plans 100-mile extension to main line in Utah.
G. L.	West Texas Gas Co.	Amarillo, Tex.			6" & 8"	100	Extension of mains.
G. L.	Western Service Corp.	Oklahoma City, Okla.			8 or 10"	110	Propose main line extension in Mo. & Kan.

3 NEW

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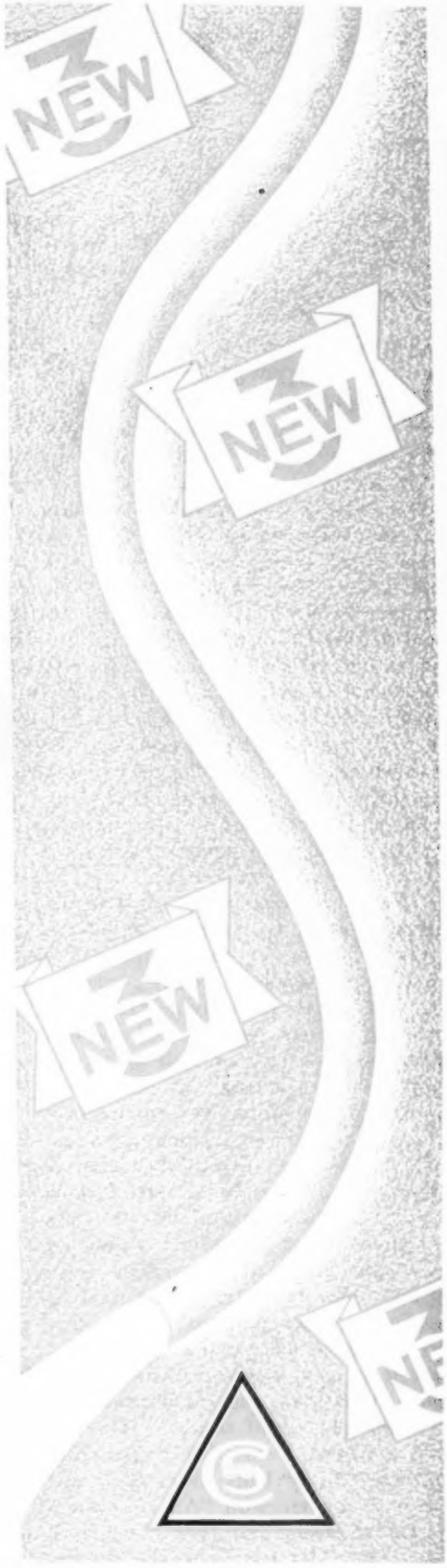

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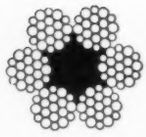
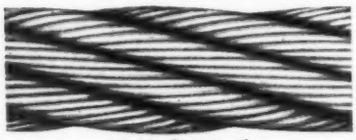
INTERNAL STRESSES *of* Wire Line

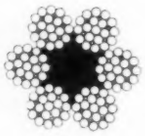
By WALTER VOIGTLANDER*



6x19 Warrington



6x19 Construction



6x19 Filler Wire

WITHOUT doubt it will be acknowledged by all engineers that a wire rope will render service in some definite relation to the stresses to which the rope is subjected, assuming, of course, lack of abuse or of corrosion. That the rope service will be greater with lower stresses is almost self-evident from the viewpoint of fatigue and has been proven in actual usage; thus it is proposed to show that relative service is *a* reciprocal index to *all the combined stresses* acting upon and within the rope. The applied axial tensile stress can be easily controlled and varied at will, but the other stresses are so greatly influenced by constructional details of rope fabrication, that their mathematical values are indeterminate except when certain of the variables are unified or kept constant for any series of tests or investigations.

Walter Voigtlander

There have been many praiseworthy attempts made to evaluate the internal stresses in wire ropes under the general heading of "bending stresses", but these stresses include not only so-called pure bending stresses, but torsional and constructional stresses as well as an undefinable "restrictional" stress that increases within a rope with the intensity of the very stresses acting upon and within the rope. It will be acknowledged that any "bending stress" formula or set of derived stress tables that does not give practical results coinciding with field results, is impractical. Some of the tables or formulas now used are applicable to moderate and larger sized sheaves, but do not predict premature failures of ropes for small-sized sheaves, and it is this aspect that has led the writer to examine more closely into the modification of the present formulas, to cover all sizes of sheaves. There has come to our attention a reprint from *Civil Engineering* of November, 1930, entitled "Heavy Duty Wire Rope and Sheaves," by B. R. Leffler, together with "An Analysis of Bending Stresses," by C. D. Meals, and "Six Formulas Compared," by R. C. Strachan. This last gives six formulas and it will be seen that each is a *straight-line formula;* that is, the bending stress is in *direct* proportion to the reciprocal of the sheave diameter. It is upon this particular point that the writer desires to differ and to develop the thesis.

Before proceeding, however, it should be pointed out that other variables *must* be kept constant if comparable results are to be secured from laboratory tests and corroborated by such field results as can be produced under like variable control. These variables are listed by Mr. Meals in the "Analysis", but are given here for ready reference: (1) Strand Construction and Relation of Wire Sizes. (2) Length of Strand and Rope Lays. (3) Quality and Size of Center in the Rope. (4) Lubrication. (5) Arrangement and Condition of Sheaves. To this list we would add: (6) Relative Speed of Rope Travel.

Each of these is worthy of a separate study, but in this regard it should be noted that the first two variables are purely details of fabrication, the third though initially a fabrication detail would also include deterioration of the core due to lack of proper maintenance, the fourth both of fabrication and of field maintenance, and the fifth and sixth are a matter of equipment design and maintenance over which the rope manufacturer has no control. All other variables being kept constant, the first variable has been found to alter service by 300 per cent; the second, by about 50 per cent; the third, by more than 1,000 per cent; the fourth, from 250 to 500 per cent, depending upon the relative sheave diameters; and the fifth, considering continuous versus reverse bends, by 250 per cent, or considering worn or pinching grooves in sheaves, by more than 1,000 per cent; the sixth, in approximately the inverse ratio of the square of the speeds. While a combination of these variables will reduce service below that rendered by any one, yet they are not entirely cumulative in their action. It has been found that a very badly worn sheave groove on a shovel with the regular sized new rope only gave one and one-half hour's service to the rope, whereas a new rope of the same grade and construction, but $\frac{1}{16}$-inch smaller, though somewhat weaker, gave four weeks' service. Again a new test rope purposely made with an inferior hemp core used on a clam-shell crane unloader gave only one hour's service as against the usual four to five weeks from the stock proper rope. These examples are cited so as to impress the necessity of definitely controlling all the variables.

It is further seen by reading the reprints mentioned, that service already rendered by a rope greatly alters the original modulus of elasticity of the rope, and also that the modulus of the same commercial rope as made by different manufacturers may vary even for new ropes. For this reason the writer suggests that if anyone tries to establish data for results of the type under discussion, that ropes all from one source of manufacture be used initially, after which other makes should be tested similarly so as properly to modify

* Chief Engineer, Union Wire Rope Corp., Kansas City, Mo.

the initial formula that may have been so established.

As a starting point for the consideration of this subject, it is found that when a rope is bent over a sheave, the strands slide past each other on the core so as more evenly to distribute the stresses set up in the strands by bending. There comes a point, however, when these strands are restricted from adjusting themselves further and the diameter of the bend where this occurs is called the "Critical Tread Diameter" of the sheave for that particular size and construction of rope. The critical sheave diameter for various constructions of rope may be taken as follows, where "d" is the rope diameter:

6x7	28d
6x19 Seale	20d
6x19 Warrington	16d
6x19 Filler Wire	16d
6x31	15d
6x37	14d
8x19 Seale	14d
8x19 Warrington	13d

Taking for example the ropes most universally used, the 6x19 Warrington and the 6x19 Filler Wire types, having the same practical critical sheave tread diameters, it has been found by laboratory fatigue tests and closely corroborated by field use on shovels and other excavating machinery, that a remarkable increase of about 400 per cent service is secured when increasing the 16d sheaves by 50 per cent to 24d diameter. This led to tests and field observations on sheaves having 36d diameter (50 per cent increase over the 24d), with only 70 per cent service increase over that rendered by the 24d diameter sheaves. From a series of such comparisons, Chart No. 1 has been prepared, starting unity service at 16d, the chart having sheave tread diameters as the ordinates and relative service as the abscissas. To this chart is added a 45-degree line which would represent the locus of relative service based on the *straight-line* theoretical bending stresses formulas. The curve whose developed equation is $y + 16 = x^{(1.13802 + .0308x)*}$ has been so laid out by choosing a proper scale for the abscissa, that the curve is tangent to the 45-degree line. In this form the visual comparison of the service relations between actual (curve) and theoretical (straight line) becomes clearer. The equation of the 45-degree line that would be tangent to this curve is $y = (4.425)x$ and the relation between the service records as expressed by the two equations is shown graphically in Chart No. 2, wherein the ordinates are the relative sheave diameters just as in Chart No. 1 and the abscissas are the ratios of the respective abscissa of the straight line to the curve values.

The practical "bending stress" in the given 6x19 types of rope as denoted on Chart No. 1 can now be obtained by multiplying the values as secured from any of the formulas as mentioned in Mr. Strachan's paper, by the abscissa values for the corresponding sheave diameters from Chart No. 2.

The above discussion deals with only one particular construction of rope, viz.: 6x19 hemp centered hoisting rope of the two designs, Warrington and Filler Wire, that have 16d for their critical sheave tread diameter; assuming also a constancy of the six variables mentioned. A decidedly different service curve and equation would result if a change is made in *any* of the six variables, the degree of difference being indicated to some extent by the above cited service variations found for each. To develop a "Chart No. 2" for any other construction of rope or for the same rope in the above discussion, but with an altered variable, would require a duplication of the shop and field data as secured in establishing our present Chart No. 1.

Conclusion

a. Because of the great influence of numerous variables upon the physical properties of a wire rope, it is impractical, if not impossible, definitely to establish "Bending Stresses" by a mathematical formula.

b. Service rendered under certain controlled conditions is in inverse ratio to the combined stresses, as indicated by actual field records; these field records are a truer index to the combined stresses than any mathematical formulas as they automatically include certain slight changes normally altering some of the variables which influence the modulus of the rope.

c. It *is* practical for any given controlled consideration of the variables cited to develop a "Chart No. 2" by which theoretical stresses may be modified to reflect relative stresses under these assumed conditions.

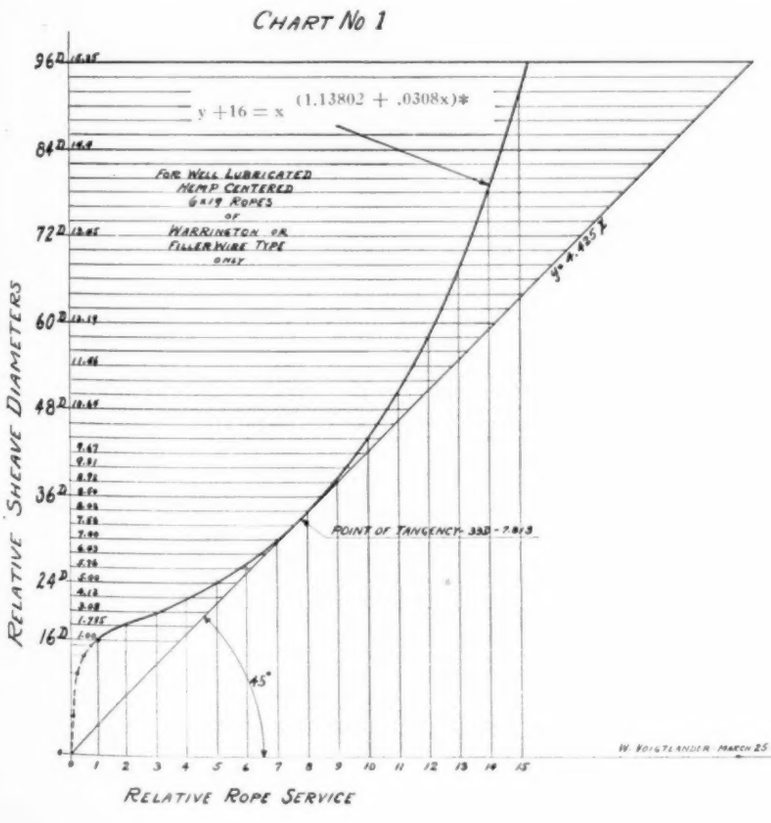
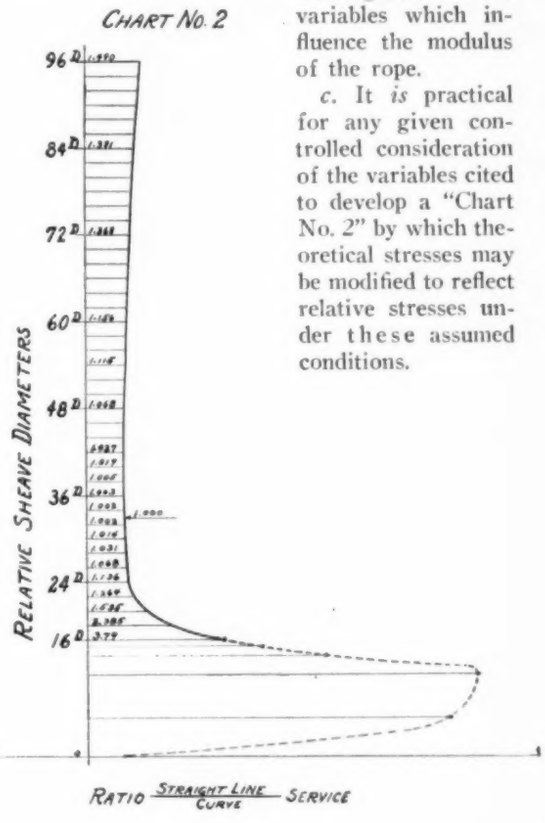


CHART No 1
y +16 = x (1.13802 + .0308x)*
FOR WELL LUBRICATED HEMP CENTERED 6x19 ROPES OF WARRINGTON OR FILLER WIRE TYPE ONLY
y = 4.425 x
POINT OF TANGENCY
45°
RELATIVE SHEAVE DIAMETERS
RELATIVE ROPE SERVICE
W. VOIGTLANDER MARCH 25 1931



The Year's Progress in

The California Natural Gasoline Industry

By
F. L. KALLAM[1]

THE past twelve months marks the first period in history in which the production of natural gasoline in the United States has shown a decline. Although the Appalachian and Indiana-Illinois fields were the only ones, aside from Oklahoma and California, to show a lesser production, the gains registered in the other areas were so slight as to fail to compensate for these declines. This lesser total production is not reflected in the lesser use of natural gasoline, however, for the past year shows a somewhat larger consumption by the refiner as compared with the previous year.

California again led as producer of natural gasoline during the past twelve months, producing approximately 37 per cent of the total U. S. production. Oklahoma was second with 28 per cent and Texas a close third with 23 per cent. Natural decline in the Seminole area and the proration of the Oklahoma City Field caused a substantial reduction in Oklahoma's production from what it could have been had the wells been allowed to flow open. This condition also prevailed in California and in certain Texas fields, but its effect was more strongly felt in Oklahoma. This was because no new fields of any importance were developed and because of the rigid curtailing of the Oklahoma City Field which prevented the equalizing of the natural loss in the older areas.

The decrease in natural gasoline production in California during the past twelve months is graphically shown in Figure 1. This decline in output is closely related to the drop in crude output, which was governed by proration rather than following the trend of natural gas production. There are a number of factors besides the volume of gas which affect the amount of gasoline carried by the gas, these in part being the quality and quantity of oil with which the gas contacts during its removal from the oil pool and the temperatures and pressures which prevail during such removal. For this reason there has been included in Figure 1 the ratio of natural gasoline produced to crude oil produced, expressed in gallons per barrel.

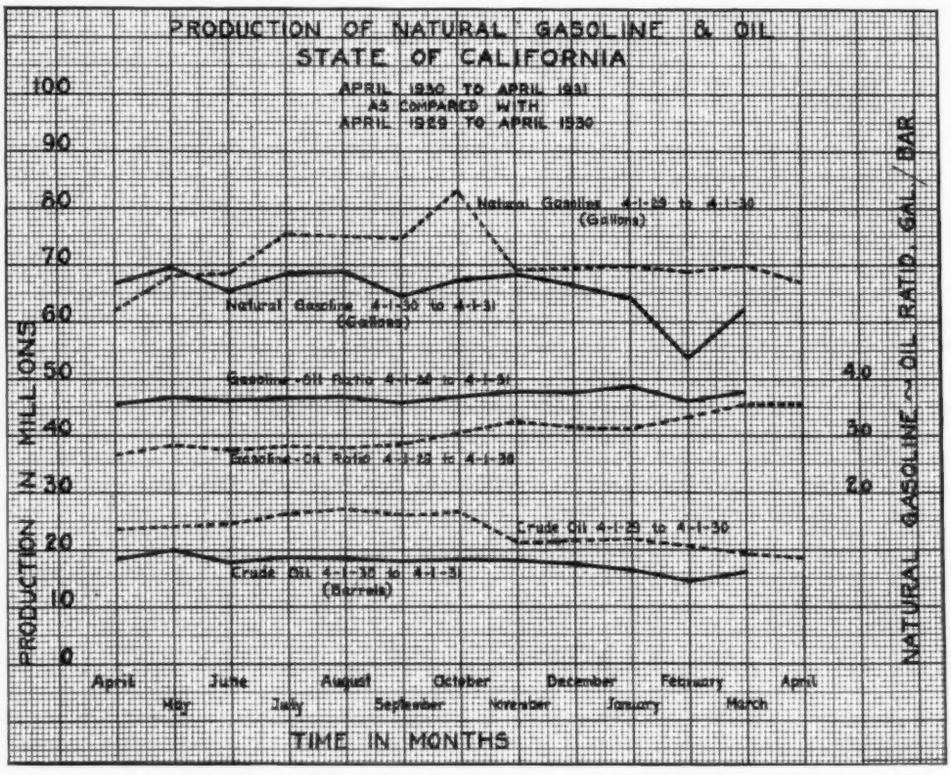


Fig. 1

Aside from the factors already mentioned it should be remembered that the amount of natural gasoline produced is also a function of the economic loading of the recovery plant, the efficiency of the extraction method itself, and the specifications or quality of the product which can be sold.

From Figure 1 it is interesting to note that from April, 1929, to October, 1929, the average natural gasoline-oil ratio for California gradually increased from 2.65 to 3.1 in spite of the fact that the oil production remained substantially constant. This was caused by the addition of efficient plant capacity and the increase in oil-gas ratio at the newly developed fields. In October, however, the California curtailment program started, with immediate decrease in crude production. This move relieved the load thrown upon the State's gasoline plant capacity to some extent, which resulted in greater extraction efficiency such that in March, 1930, the natural gasoline-oil ratio had risen to 3.55.

The Kettleman Hills field, which had begun to be a serious factor in the early part of 1930, was chiefly responsible for the increased gasoline-oil ratio by April. During this period Kettleman Hills compensated for the losses in the rest of the State, although it is also probable that the newer plants in this field also contributed by reason of their higher extraction efficiency. The magnitude of this field is evident from the figures of August in which the seven producing wells resulted in about 15,250 barrels of crude per day. From the accompanying gas there was manufactured 520,000 gallons of natural gasoline, representing 22 per cent of the total California production. These figures are truly re-

[1] Consulting Engineer, Foster Wheeler Corp.

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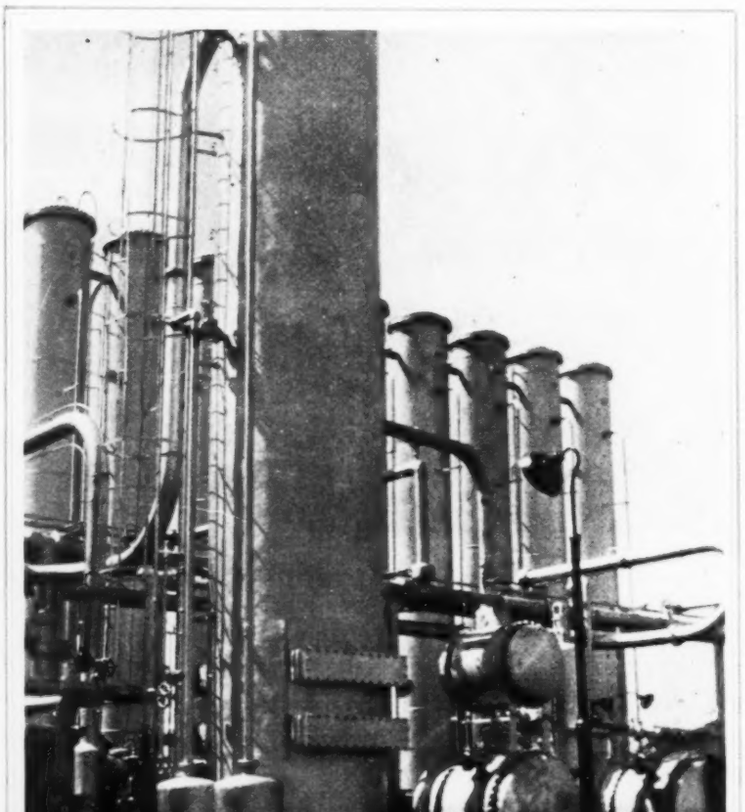
markable when it is remembered that the entire yield from this field during the calendar year of 1929 was insignificant. The natural gasoline-oil ratio from the above figures is well over 34 gallons per barrel which is in considerable contrast to the State average at this time of 3.7. It is, therefore, little wonder that Kettleman has completely overshadowed the other new California fields of Protrero, Playa Del Rey and Belridge.

From August to the present time the California crude production has shown a gradual decline due entirely to proration measures. On the other hand, the natural gasoline production has been fairly well maintained with the exception of a decided drop in February, which may be attributed largely to the decline at Kettleman Hills. With the completion at this time of the latest well in the field to a depth of 8,100 feet, the oil to gas ratio was of the order of 1,000 to 2,000 cubic feet in contrast to the majority of other producers where this ratio is, and has been, around 40,000 cubic feet of gas per barrel of oil produced. With the existence of substantial production on a low gas oil basis thus definitely established for Kettleman Hills it is reasonable to believe that operators will pass up the Elliot zone and center their activities in the future on the deeper Ochsner sand. This plan will have direct bearing on the quantity of natural gasoline produced as indicated by the February figures.

The unusual qualities of the crude oil from Kettleman Hills, 60 A. P. I. gravity yielding 75-85 per cent gasoline with a residuum resembling a light distillate instead of the usual heavy-ends, was at once recognized as a menace to the California price structure. Had not curtailment been started at the outset of development of this field the West Coast would have been literally flooded with crude oil and natural gasoline. This drastic action, taken in October of 1929, made effective (despite opposition) the curtailment of further development on an extensive scale, and at the same time gave birth to a unit plan of field operation. Towards the end of 1930 the Supreme Court of the State upheld the constitutionality of the previously enacted State's gas conservation law which is reflected in the gasoline-oil ration in Figure 1.

The unit operation scheme became a reality in April of this year when control was assumed of the wells and equipment in Kettleman Hills, the Association being a duly incorporated company operating under the laws of California. This Association controls 10,800 acres in the North Dome district and is a new experiment in unit operation which should result in an orderly development preventing future upsets in the market situation, economic waste, and excess production.

Even before the advent of Kettleman Hills as a major manufacturer of natural gasoline, the specifications for this material had begun to change. This was in line with the trend in other parts of the country where manufacturers had installed rectifying equipment which enabled them to make a closer separation between the desirable and undesirable properties of their product. However, even in the marketing end, the Kettleman Hills development played a big part, resulting in the bringing about of important changes in specifications which have been accepted by the buyers, and hence, by the manufacturers.



Still with two integral heaters.

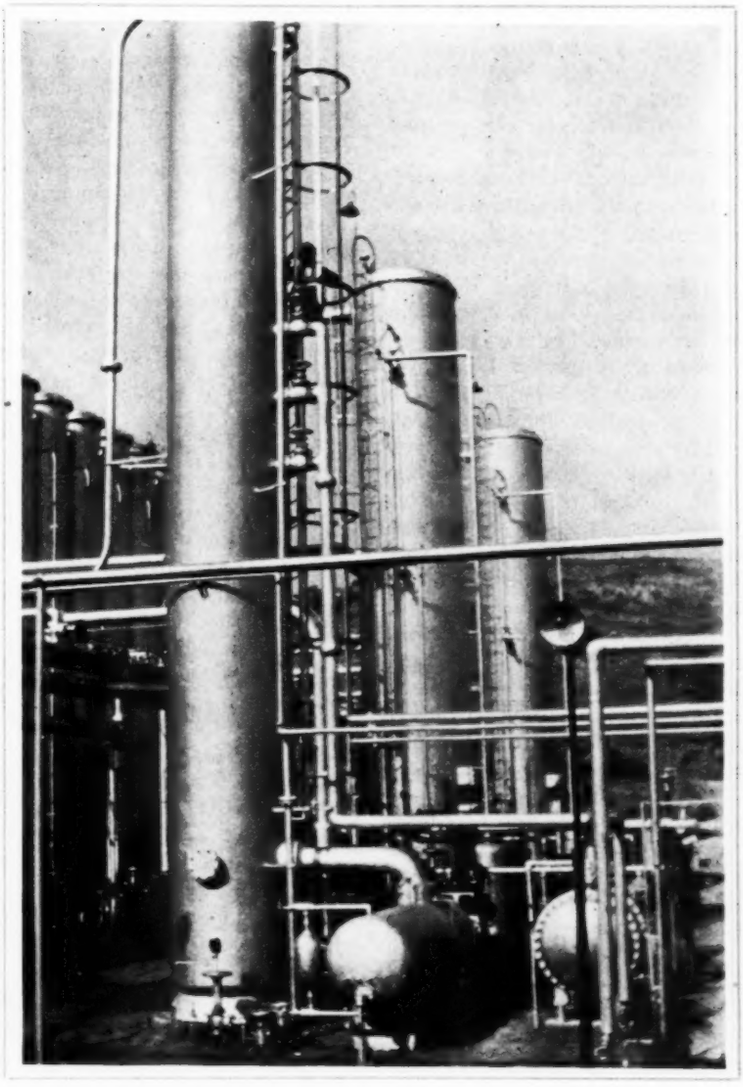
As the Kettleman District brought about a condition of overproduction, and as it was at a greater distance from the refining centers of the State and dependent upon pipeline for movement of the product, the buyers from the start were able to demand and obtain a gasoline having an Engler recovery of not less than 96 per cent. It was, therefore, necessary to make this recovery, and even as high as 98 per cent, in order to encourage the use of natural gasoline. One year ago the bulk of the gasoline output did not exceed 90 per cent recovery with a substantial part of it not exceeding 85 per cent. Such a large output of 96 recovery gasoline from Kettleman Hills has been reflected in the purchases made in all other areas in California.

The interdependency of natural gasoline prices and refinery motor fuel prices has again been well established during the past twelve months, following the correlation which has been closely observed since May of 1929. Where the ratio was disturbed there followed almost immediately a recovery of one or the other products, thereby restoring the apparent equilibrium of prices. Natural gasoline was maintained practically constant at 7.5 cents per gallon for the first ten months of 1929, with a gradual decrease to around 6.0 cents towards the closing months and early part of 1930. With the advent of the present motor fuel price war the price for natural has shrunk correspondingly to approximately 3.0 cents per gallon. Many manufacturers are

perfectly willing to move their commodity at this figure rather than interfere with their production of dry gas for which there is a steady demand.

It is apparent that as long as the refiners are the chief customers for natural gasoline they will always be responsible for the price relationship. Most refiners have found it expedient to curtail their purchases of natural for blending purposes when the price of this commodity gives them a disadvantage in respect to refiners who rely upon the modern facilities at their own plants for a comparable grade of motor fuel. Obviously the refinery will not purchase natural gasoline to produce a blended fuel which is cheaper, nor will the refiner buy natural gasoline, at any price, if he cannot move his own product.

The production and use of liquefied petroleum gases practically doubled in California during the past year as compared with the previous year. The number of installations making this material, did not, however, increase even in view of the added interest shown in the manufacture of these various by-products. Without doubt the outstanding development for these materials occurred in the marketing and distributing ends, especially in connection with the use of the butanes. There was a considerable number of central station butane plants installed in communities too small to support a gas service of the ordinary manufactured or natural type. In these stations, butane is mixed with air and the resulting mixture distributed and metered to consumers in the same manner as other gas consumers are served. Several communities in Oregon and Washington, as well as Northern California, received their first gas service in this manner. One company operating such plants is a subsidiary of one of the major California oil companies. Of technical interest in connection with these liquefied gas plants has been the development and use of special tank trucks on the Pacific Coast for making the required bulk deliveries to inland towns not located on railroads.



Rectifying unit in foreground, double distillation unit in background.

The California natural gas conservation law was originally enacted because it was brought out that the waste of gas was approximately equal to the utilization. A condition, by the way, not alone confined to California, but also found to exist in all states which have flush production. Relief for this situation has mainly been brought about by the construction of additional pipe lines to Los Angeles and San Francisco, so that now over 85 per cent of the gas used in California is natural gas. During the past year natural gas has made tremendous strides in the industrial districts of San Francisco and Oakland, where it has replaced the use of oil to a very great extent. The sale of residue plant gas has been a life-saver to many of the natural gasoline manufacturers because of the steady and increasing market for this material. At present many of the manufacturers are studying the possible utilization of dry natural gas for the production of numerous valuable chemical products.

In July the third gasoline pipe-line from Kettleman Hills to tide-water at Avila was completed, a distance of 88 miles. Construction work will be finished this month on the Associated Oil Company's line from Belridge through Kettleman Hills to a terminal at Monterey on the Coast, giving Kettleman Hills three outlets direct to tide-water composed of 312 miles of line. Gasoline sent through these lines can be loaded direct to tankers through submarine lines at each of the terminals. One company recently completed a shipment in this manner for export movement in which the gasoline had a vapor pressure of 15 pounds absolute at 100 degrees F. and a recovery of 98 per cent. By reason of these facilities California has been able to continue to move over 90 per cent of its natural gasoline via pipelines, and this means of transportation has not yet reached its maximum development.

Of that natural gasoline not shipped by pipeline or pipeline and tanker, insulated tank trucks and tank cars handle about equal amounts.

During the past twelve months California added close to 1,000,000 gallons daily capacity to its natural gasoline plant operations. Fewer but larger units summarizes the trend in the development in California, and this trend is typified by the development in the Kettleman Hills area. At present there are a total of 138 plants operating and 20 shut down, one of the latter being of 130,000-gallon capacity, which has never been placed in operation. During the preceding twelve months there were 145 plants in operation. The Long Beach Field continues to rank first in point of operating capacity among the 27 fields, but will shortly be surpassed by Kettleman Hills. Santa Fe Springs

is third in importance, having a capacity of 696,375 gallons. These three fields account for more than half of all the capacity within the State.

The difference between the average size of plants in various sections of the country is very pronounced. For example, the average size plant in Pennsylvania is 1,000 gallons daily, in the Mid-Continent 6,000 gallons, and in California 25,000 gallons. California has several plants rating 100,000 gallons daily in addition to the 150,000-gallon plant of the General Petroleum Company at Santa Fe Springs. The Norwalk Company has a 120,000-gallon plant at Santa Fe Springs; Shell Oil Company's Long Beach and Ventura plants have a combined capacity of 312,000 gallons; while the Kettleman Hills Field has the following capacity plants:

Standard Gasoline Company	3—130,000-gallon plants
Los Nietos Producing and Refining Company	1—100.000-gallon plant
The Texas Company	1—100,000-gallon plant
Western States Gasoline Co.	1—140,000-gallon plant
The Superior Oil Company	1—130,000-gallon plant

It is interesting to note that these seven Kettleman Hills plants have a gas capacity of 800,000,000 cubic feet per day, the absorption taking place at 450 pounds gauge.

The large unit plants in California have been brought about by many factors in addition to the advantage of lower unit operating costs, although quantity production is recognized as a vital factor in decreasing production costs to meet the ever-increasing intensity of competition. The expense to develop the newer fields has been increased due to the necessity of drilling to very great depths to reach the oil and gas, and this has quite naturally limited the number of individuals and companies operating in these areas. Because of the immensity of the undertaking, those participating have protected themselves by leasing as much surrounding territory as is available before going ahead with development work. Then as wells are brought in, long gathering lines are used and the gas brought to a large central gasoline plant. This method has been particularly favored because of the high pressures existing in the more recent California fields. Then, too, some producers find it more advantageous to sell or lease their gas to some natural gasoline manufacturer who already has a plant in the field.

Present gasoline prices, high cost of oil field development, and the tendency towards unit or group operation will foster only the installation of large gasoline plants in the future. The manufacturer, after passing through the unprofitable period at hand, will also be less likely to rush into new fields with plants as he has in the past. He will first want to see these fields prove that they will be able to support relatively large units, operating at full capacity over reasonable long periods of time. Despite improvements in design and economies effected by equipment manufacturers, and with the prices in effect in California during the past month (3.0 cents per gallon), it is estimated that it would be necessary to have at least a 20,000-gallon production in a new field in order to justify the installation of a gasoline plant.

There has been little improvement in gasoline plant design during the past year, all of the plants installed being conventional and following practices established in California a year and a half ago. In a number of cases steam turbines were operated with high pressure dry-gas, and in one instance, on 40-pound dry-gas. In the large plants installed the distillation system was split into two units with the idea that such an arrangement offered a far greater degree of flexibility in operation. The past twelve months has also probably seen the last of wood framed buildings in California gasoline plants, the accepted standard being the sectionalized fabricated steel building. The number of bubble plates in absorbers has been increased, 20 to 22 now being common practice. Likewise, in the case of rectifiers, the number of plates per column has increased, one installation being equipped with 50, while several others contained as many as 40, the average unit, however, containing only 30 plates. A second boiler plant for gasoline plant service was installed consisting of H. R. T. boilers fitted with waterwalls and superheaters. On the whole, the plants installed, and improvements made in the older plants during the past year have again demonstrated the value of the specialized talent to the industry.

The most commendable improvement during the year was the use of an absorption oil cleaner by the Union Oil Company through the efforts of C. D. Gard. What is more remarkable, is that the industry as a whole recognized the great need of a commercial device of this type and quickly adapted it into all the new plants and as an auxiliary in many of the older ones. The oil cleaning device is not a filter, but is strictly a small steam still through which approximately ½ of 1 per cent of the plant's lean oil is continuously passed. The distillation is carried out either at approximately atmospheric pressure or at a vacuum by the use of stripping steam in the conventional manner. The vaporized absorbent is condensed and returned to the main system while the residue, consisting of the undesirable heavy tarry substances and dirt, is disposed of to waste. In addition to improving the condition of the lean oil, actual tests have shown that the cleaned oil will remove sediment and gummy deposits from the absorber, stills and heat exchangers, and that by the continual use of the device it becomes unnecessary to ever change the oil in the system. Several plants are obtaining these same results by the use of small tube stills through which the side stream of absorption oil is passed, in which cases no steam is used in the process.

One other gasoline plant located at tide-water has demonstrated that it is possible and economical to use ocean water for cooling purposes. Why this was not done sooner is now hard to understand. In this case the sea water is pumped from the ocean into the basin of the original fresh water cooling tower, the basin having been extended sufficiently so as to fully submerge the atmospheric coolers and condensers located in the tower. The water enters at one end of the basin and overflows at the other, returning by gravity to the sea. The system is thus an exact duplicate of the conventional condenser box in a refinery. By attaching zinc plates to the cooler surfaces, the latter have been protected from the effects of electrolysis, it being necessary, of course, to replace these plates from time to time.

At one of the newer plants the high pressure wet gas is being cooled before introduction into the absorbers by refrigerating with a propane mixture obtained from the rectifier reflux. This propane is handled in a closed circuit exactly as is ammonia in the conventional compression refrigerating cycle. The absorbent oil can be precooled in a like manner by this same system.

One rectifying unit has been placed in operation in which three products are obtained from a single column, the third product appearing as a side-cut from the upper portion of the tower. This method has been used for years in refinery practice and its adaption to natural gasoline practice is not surprising. Several central rectifying plants were installed during the year of such design as to produce a motor fuel, blending gasoline, and liquefied petroleum gases.

In conclusion, it may be said that California is now faced with problems of an economic nature which will force the development of ways and means for utilizing portions of the present product which can no longer be placed in the finished gasoline, and which can no longer be wasted to the atmosphere. Technical development will follow fast and there will soon be super-fractionation of the present product, resulting directly in a motor fuel competitive with the present premium gasolines.

Causes, Characteristics and Methods of Treating

Oil Field Emulsions

By W. F. CLOUD, *Associate Professor of Petroleum Engineering, University of Oklahoma*

AN emulsion is a mixture which contains two liquid phases, one of which is dispersed as globules in the other. That liquid which is broken up into globules is called the dispersed or internal phase, whereas the liquid surrounding the globules as a film is known as the continuous or external phase.[1] The two liquids must be immiscible, or nearly so.

Emulsions have been divided into two groups, "stable" (tight) and "unstable," depending upon the tendency of the mixture to remain as fixed or upon the rapidity with which the respective liquids coalesce and separate into distinct layers.

Oil field emulsions are commonly called "cut oil," and a well that is producing finely-divided globules of water with the oil is said to be "cutting its oil." The term "B. S." (basic sediment) is a field expression originally applied to any substance that settled to the bottom of storage tanks, but now the term is usually interpreted to mean any sand, silt, or "cut" material which may separate from clean oil when placed in a tank.

[1] Clayton, Wm.—"The theory of Emulsions and Emulsification", 1923, P. Blakiston's Son & Co., Philadelphia, Pa.

Emulsions often exist in both the water-in-oil and the oil-in-water types. However, most oil field emulsions are of the water-in-oil type. In order for crude oil emulsions to remain fixed or stable, a third substance besides the oil and water is necessary. This third element is known as the emulsifying agent. In addition to this, a variable amount of stirring or agitation is necessary. Paraffin base oils, however, in contrast with those of asphaltic base, are not readily susceptible to emulsification, even though violent agitation does occur. As an example of this, the paraffin crudes of Pennsylvania and the Appalachian fields may be contrasted with the asphalt base oils of California, Mexico and Russia, where stubborn emulsions are common.

The type of emulsion produced depends upon the nature of the emulsifying agent. A water-soluble colloidal substance, either organic or inorganic, if mixed with oil and water and agitated, will form an oil-in-water emulsion because some colloids are more readily wet by oil than by water, and will be dissolved by or remain in suspension in oil, whereas an oil-soluble colloid will produce a

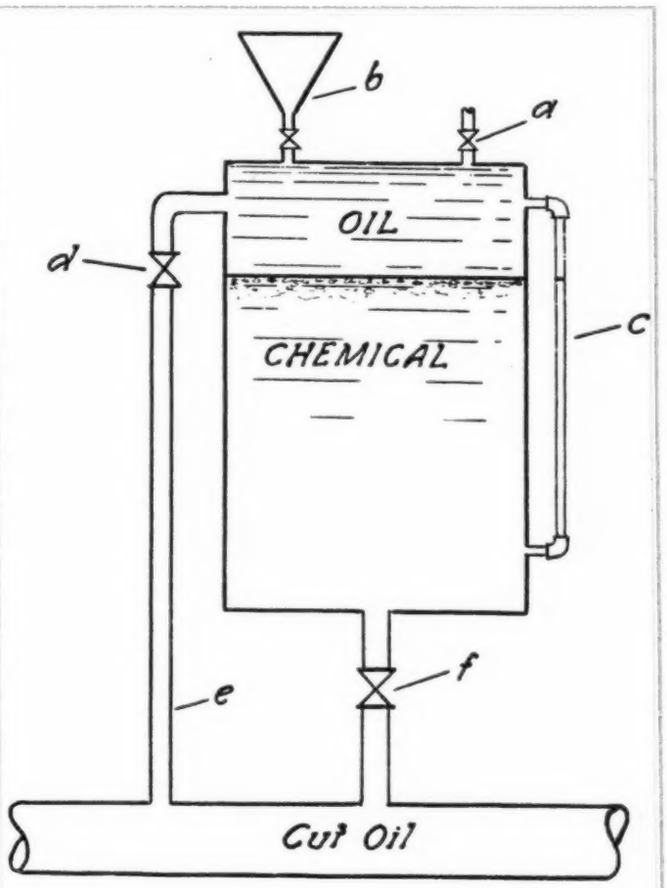


FIGURE 3.

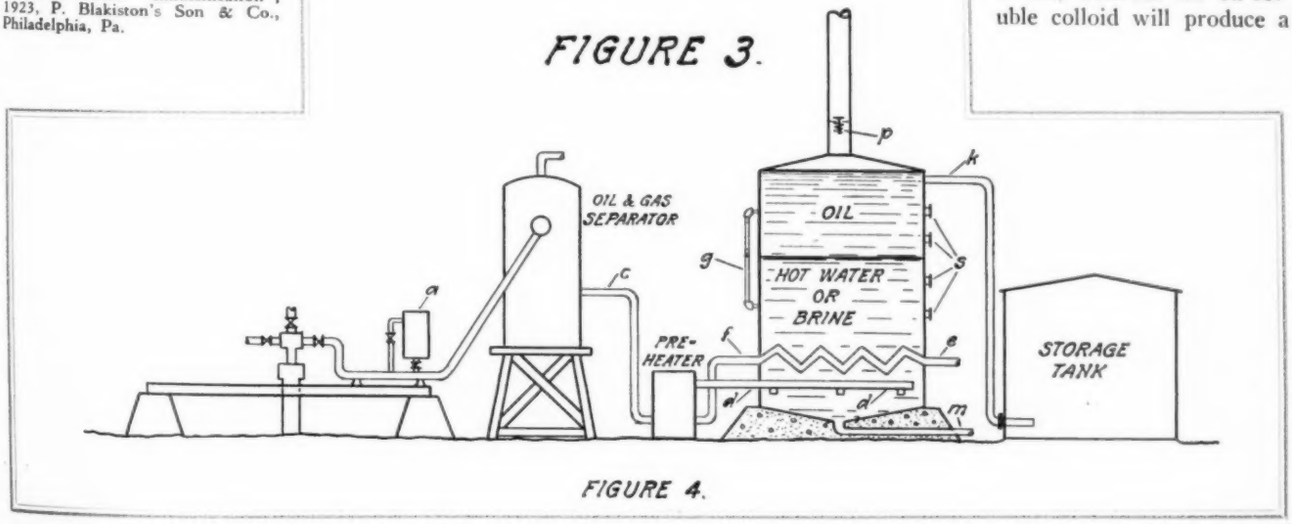


FIGURE 4.

water-in-oil emulsion.[2] On the other hand, it is believed by many authorities on this subject that the degree of emulsification depends upon the size of the particles which compose the emulsifying agent, whether they are soluble or not, and that the size of the enclosed globule as well as the stability of the emulsion vary with the fineness of these particles. Iron, zinc, and aluminum sulphates, silica, calcium carbonate, magnesium hydroxide and iron sulphide are all more or less insoluble in an oil-and-water mix, but they can serve as emulsifying agents when finely divided; the larger the percentage of suspended solids, the more stable and stubborn will be the emulsion.

Dow[4] has described some types of gas traps used effectively at flowing wells to eliminate the formation of emulsions beyond the casing head.

When wells that are producing silts and various emulsified "salts" dissolved in the water accompanying the oil are swabbed, emulsions are quite likely to form. Agitation or atomization in this case is a result of slippage or leakage of the mix between the casing and the swab rubbers or cups as the swab is being pulled upward. This orifice action will occur at high velocity in deep wells or when a well is being swabbed rapidly. Also, as a swab is lowered through the fluid the fluid will be agitated to a certain extent as it passes through the check valve of the swab.

Treating emulsions is a paramount problem to the producer because pipe line or purchasing companies will not usually accept oil that contains more than one or perhaps two per cent emulsion, silt, water, "B. S." or foreign substance.

Choice of the most satisfactory method of treatment depends not only upon the initial cost and installation cost, but upon the operating costs, the type of crude and the per cent of emulsion, the amount of evaporation that may occur while treating, and the time involved in treating the daily volume of cut oil.

At the present time there are five practical methods used to break down oil field emulsions:

1—Heating in closed systems.
2—Treating with electric current.
3—Centrifuging.
4—Treating with chemicals.
5—Various combinations of the above.

Heating emulsified oils in an ordinary locomotive type of fire-tube boiler has been used to good economic advantage, especially in the Mid-Continent fields, when used in combination with the chemical method of treatment.

Usually the chemical is added as the cut oil passes through a flow line to a heat exchanger before it enters the boiler. The boiler should be kept full of brine solution to prevent local overheating of the oil. Usually the cut oil enters the boiler at the stack end through the feed-water openings, and is discharged with part of the brine at the steam dome. However, the reverse of this flow is often practiced. After leaving the boiler it may be practical to pass the heated oil through a "washing" tank before the mixture of oil and water is conveyed to a settling tank.

The boiler is usually fired by gas burners that are controlled by thermostats in order to prevent overheating the oil. The temperature maintained should never exceed the initial boiling point of the crude oil that is being treated, because installations of this sort are not usually designed to operate under much pressure, and they do not ordinarily provide for the cooling and condensing of hydrocarbon vapors.

The treating plant illustrated in Fig. 1 is typical, with a few exceptions, of combination chemical and heat treatment installations when fire tube boilers are used.

Cut oil from the individual wells or tanks, which has been charged with chemical, enters the manifold, thence is pumped into the boiler at (k) and is discharged through a six-inch line at the dome. This line is elevated where it empties into the "boot" at (m), so as to maintain the boiler dome full of oil and brine. This prevents scorching the oil while in the boiler. From a point near the bottom of the "boot" the oil is carried into the skimming tank and discharged downward through a six-inch spreader. Oil drain (p) carries the skimmed oil over into another similar tank, where it is discharged by a similar spreader. Four-inch upper spreaders, assisted by the siphon arrangement, are used to control the salt water level in the two tanks. A four-inch relief line leading from the top of skimming tanks discharges the hydrocarbon vapors.

The distillation method of treating emulsified oil has been used mostly in California. While the initial cost of this method is high as compared to other methods, the maintenance cost is low, and there is little or no loss due to evaporation.

The process usually consists of passing the cut oil through a long heat exchanger [made by running tubing through several joints of casing flanged at each end and placed horizontally, as is shown in Fig. 2 at (a)], where the oil is usually heated to about 150 degrees Fahrenheit. Thence the oil passes through a series of shell or tube stills, where it may be heated from 250 to 450 or 500 degrees, depending upon the nature of the crude, the stability of the emulsion and the end point of the distillate obtainable. Most of the water can be drawn off at the lower temperatures from the bottom of the low temperature stills, but some of it is vaporized and passes out with the hydrocarbon vapors into the cooling tower or condensers, where both vapors are condensed into free water and gasoline or naphtha. The hot, clean oil from the stills and the hot oil receiver or separation tank is circulated back through the heat exchanger before going to storage.

The equipment and method of processing shown in Fig. 2 varies somewhat from the general procedure described above. Instead of passing the cut oil directly into shell or tube stills, it is circulated through a series of high- and low-

[2] Briggs, T. R.—Journal of Industrial & Engineering Chemistry, Vol. 13, No. 11, Nov., 1921.
[4] Dow, D. B.—"Oil Field Emulsions"—U. S. Bureau of Mines Bulletin No. 250.

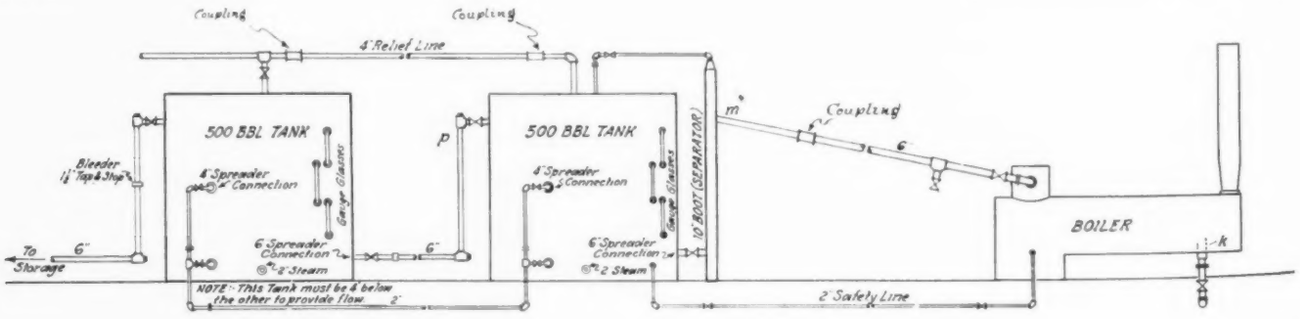
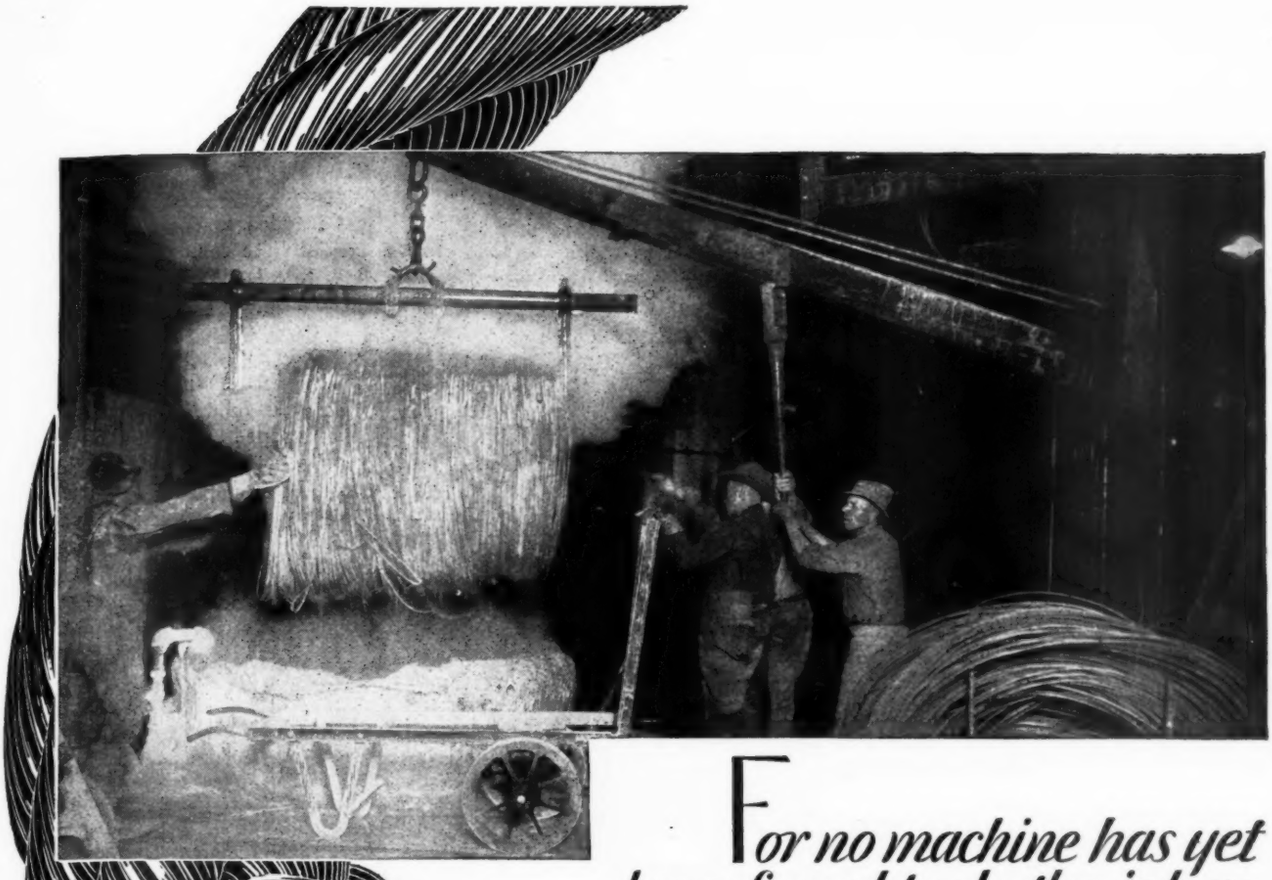


FIGURE 1



For no machine has yet been found to do the job as thoroughly!

THE cleaning of rods, that will become wire and later Wickwire Spencer Wire Rope, is far too important a process to employ other than the most thorough methods. While the Wickwire Spencer Rope plant is equipped with the most modern labor-saving machinery, there are several steps that still employ costly manual methods... operations that are better performed by hand. Here, quality of product has, does and always will take precedence over production economies.

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pressure steam stills (b), which are heated by high-pressure steam from a battery of water-tube boilers. The lower row of steam stills are operated at 150-200 pounds pressure and carry superheated steam.

Countercurrent flow of oil through one-inch pipes is provided in both series of the steam stills. Low-pressure steam and hot water are circulated back into the boilers by a pump (d). The hot oil, hydrocarbon vapors and the steam generated by heating the water in the emulsified oil considerably above the boiling point of water, are carried from the steam stills by an insulated line (e) into a pressure tank, where the hot oil and vapors separate. Clean oil is then passed back through the heat exchanger before going to storage (p). This flow line (g) should be insulated or buried.

Vapor line (f) conveys the steam and hydrocarbon vapors to a cooling tower, where they are condensed and discharged (h) into a separation or settling tank. Gasoline distillate can be withdrawn at (m) and the water at (k). Countercurrent flow of steam from boiler is indicated by arrows at (c) and (p).

Dow[4] has fully described and illustrated the various electrical treaters and methods used in treating emulsified oils.

The globules of emulsion, which are often electrically charged, when subjected to a high potential alternating current become further charged. This action breaks the tiny film of oil that envelops the water, causing the water to coalesce into larger drops, which, due to their greater density, settle to the bottom of the tank. Stress and strain is the reaction that produces results. The action is similar to that of a series condenser rather than to that of a conducting circuit. The microscopic water droplets are the electrodes and the oil film is the di-electric which is ruptured by the high voltage, permitting the adjacent positively and negatively charged drops to neutralize themselves by uniting and thus enlarging.

Chemical Treatment

As has been stated, the tiny drops of water are usually negatively charged. The water particles may be made to coalesce by the addition of certain electrolytes, such as acids and iron salts.[5] It may seem difficult to imagine that emulsions containing 40 to 60 per cent water can be accounted for by preferential ionic absorption. Such water-soluble colloids as sodium oleate and the sulphurous acids usually break down these emulsions or render them unstable. Care must be exercised in order to add exactly the correct amount to neutralize the oil-soluble colloid. Also, it is well known that variable mixtures of ether, benzol and carbon disulfide will break emulsions.

The chemical composition of commercial chemical treating agents may vary considerably, depending upon the nature and characteristics of the crude to be treated. In order to obtain the best results at the least expense, samples of the crude to be treated should be sent to the testing laboratories of the companies that sell oil-treating chemicals. After experimenting with the samples in the laboratory they will be able to ship the chemical combination that is best for that particular crude.

If the chemical is to be added to the cut oil in a flow line—as, for example, between the casing-head and the gas trap—or to a gravity flow line leading from storage tanks to the treating plant, a container known as a chemical lubricator (see Fig. 3) is often installed on the line. Referring to Fig. 3, the air vent (a) is opened and the chemical poured in through the funnel (b) until the gauge glass (c) shows that the lubricator is full. Then the valve (d) on the by-pass line (e) is opened, admitting oil pressure above the chemical. The discharge valve (f) is then regulated to obtain the best mixture in the flow line. This type of chemical feeder requires little attention after proper regulation is obtained.

If the line is under little or no pressure—or it may be that the cut oil is being pumped to the treating plant from a tank or sump—it may be necessary to install an elevated chemical tank near the pump. It should be several feet above the oil pump. Using a valve and tee, a connection can be made to the suction end of the pump so that by regulating the valve the proper amount of chemical can be fed into the pump with the oil at each stroke of the piston.

Fig. 4 illustrates a common practice of combining the chemical and heat-treating methods at a flowing well or at a well operated by air-gas lift. The chemical lubricator (a) is installed on the flow line between the Christmas tree and the gas trap. Better results will be obtained if the gas trap is located 150 or 200 feet from the well, as this insures a more intimate mixing of the chemical with the oil. From the oil and gas separator the mixture is carried by the oil discharge line (c) through a steam-operated preheater, which is heated by discharge steam (f) from the steam coils in the treater, thence into the treater, as shown at (d). Steam enters the treater at (e) and circulates through the steam coils in order to heat the brine and the oil. The treater should be kept about one-half or two-thirds full of salt water. This can be done by watching the gauge glass (g) and by operating an inverted U-tube siphon line placed vertically along the outside of the tank. The fluid column may be checked also at intervals by use of the stop-cocks (s). The treater is protected against failures due to excessive pressures by the pressure relief valve (p) in the stack. Sand, silt and some "B. S." must be removed at intervals through a drain line (m) connected to the center of the tank bottom. The line (k) skims off clean oil, which gravitates to storage.

[4] Dow, D. B.—"Oil Field Emulsions"—U. S. Bureau of Mines Bulletin No. 250.

[5] Emulsification Symposium—Journal of Industrial and Engineering Chemistry, Vol. 13, Nov., 1921.

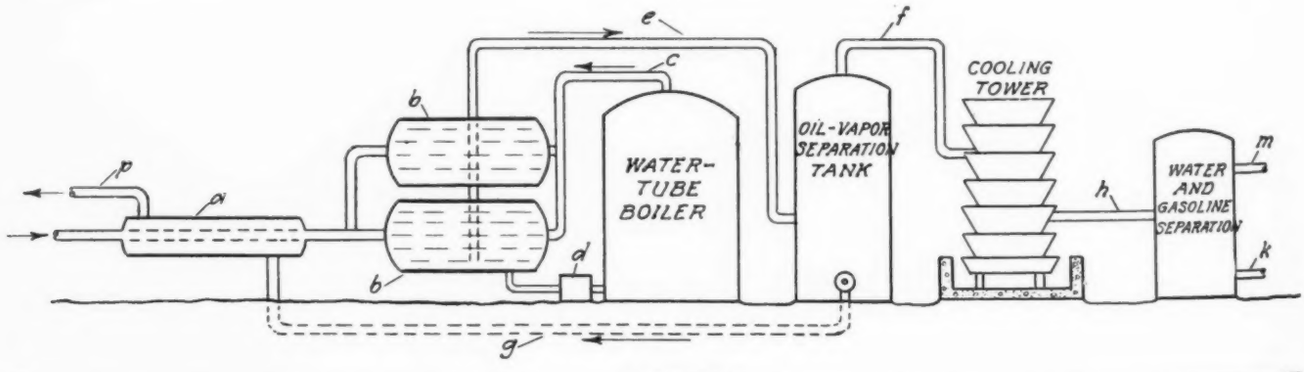

FIGURE 2.

View showing a 7½ H. P. 1800 r.p.m. Louis Allis "Explosion-Proof" Motor... one of 7 operating out-of-doors at a large natural gasoline plant near Seminole, Okla.

Outdoors, too... Louis Allis "Explosion-Proof" motors are needed, and *used*.

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Although installed out-of-doors, the driving motor is frequently surrounded by explosive vapors from the pump... because gasoline vapors, being heavier than air, cling to the ground.

Consequently, Louis Allis Type E "Explosion-Proof" motors were selected... to protect this modern plant from the fire hazard incurred wherever non-approved motors operate in explosive atmospheres.

With L.A. "Explosion-Proof" motors, you are not *guessing* at safety. Your *assurance* is the fact that these motors are definitely tested, approved, and *labeled* by Underwriters for Class I explosive atmospheres where petroleum vapors may occur.

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Louis Allis "Explosion-Proof" Motor 1/4 to 100 H.P.

Approved by Underwriters' Laboratories for use in Class I explosive atmospheres wherever petroleum products are made, used, or handled. Widely used in refineries and natural gasoline plants as direct drives for pumps, centrifuges, blowers, unit heaters, etc.

WARNING!

Do not confuse the Louis Allis "EXPLOSION-PROOF" Motor with non-approved so-called "vapor-proof" motors. Real "EXPLOSION-PROOF" motors must be specially constructed and must pass severe explosion tests to be approved by Underwriters' Laboratories for use in Class I explosive atmospheres.

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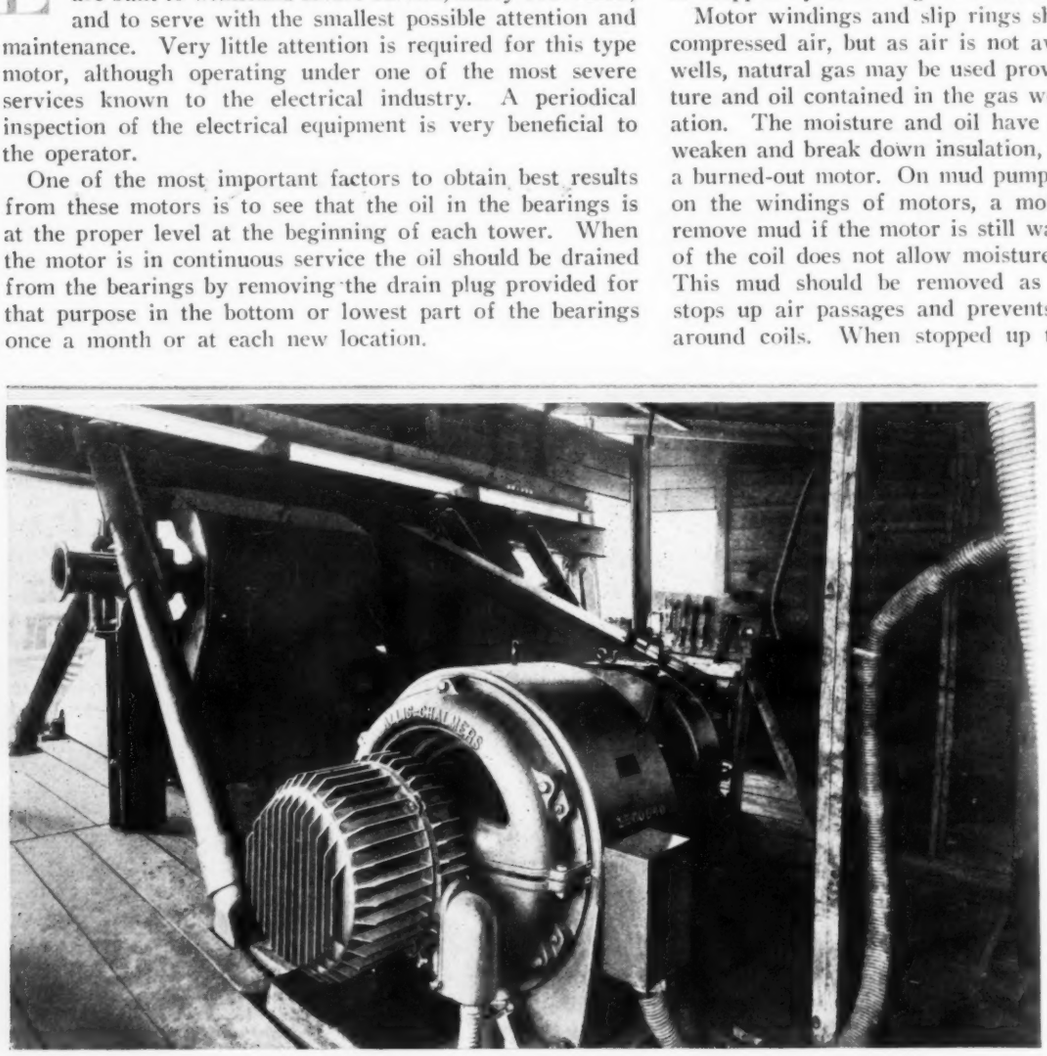
One of the most important factors to obtain best results from these motors is to see that the oil in the bearings is at the proper level at the beginning of each tower. When the motor is in continuous service the oil should be drained from the bearings by removing the drain plug provided for that purpose in the bottom or lowest part of the bearings once a month or at each new location.



250/85-H. P. protected type drilling motor operating drawworks at Hall & Briscoe's No. 2 Lindsay, Oklahoma City field.

A good standard brand oil of S. A. E. rating should be used. In severely cold weather a light, free flowing oil should be used in preference to a heavily bodied oil. Most motors are self-oiling; a large ring hanging down into the oil reservoir by rotation on the shaft supplies oil to the top of the bearing. These rings should be inspected once each tour—especially if the motor has been stopped for some time —to see that they are revolving freely.

In replacing the drain plug, it should be tightened securely, as vibration might cause it to back out, letting the oil drain, which might not be noticed until bearings are damaged or burnt out. The bearings need not be washed with kerosene unless they contain grit or other foreign matter. When refilling bearings, care should be taken to have the overflow cap open so any surplus oil may run out. Too much oil is injurious, as it runs out the bearing ends and is thrown on windings, causing deterioration of insulation. Any leakage around drain plug or oil level gauge should be stopped by removing and leading.

Motor windings and slip rings should be blown out with compressed air, but as air is not available on most drilling wells, natural gas may be used providing it is dry, as moisture and oil contained in the gas would endanger this operation. The moisture and oil have a tendency to soften or weaken and break down insulation, which would soon cause a burned-out motor. On mud pumps, where mud often gets on the windings of motors, a moist rag may be used to remove mud if the motor is still warm, as the internal heat of the coil does not allow moisture to penetrate insulation. This mud should be removed as soon as possible, as it stops up air passages and prevents free circulation of air around coils. When stopped up the motor will run hot, cutting down its efficiency.

Slip rings should be kept clean and smooth. When rough or pitted, a carborundum stone may be used to dress them down, removing pits and rough places, finishing up with 2/0 emery cloth or small sand stone. If rings are out of round, rotor should be sent to a machine shop and rings turned down in a lathe. A field job may be accomplished by use of a tool post grinder fastened or secured to the frame of the motor. Be sure to insulate the grinder from frame of motor. Start motor and, with grinder motor running in opposite direction, pass over rings with machine handle. This operation is slow and tedious and should be used only in case motor cannot be out of service. An experienced electrician or machinist should have charge of this work. When rings are out of round the motor does not operate efficiently, as brushes do not make good contact and also heat and chatter.

The brushes should be removed from the brush holders, wiped with dry cloth, and should be free, but not loose, in holder, and have no more tension on springs than is necessary to give good contact. The face of the brush should make at least 90 per cent contact. If they do not, they should be fitted in with sandpaper. When brushes fit properly, the slip rings turn a dark brown color and are smooth and glossy. After sanding in brushes, all carbon dust should be blown from rings as moisture and oil collect dust and might cause a short or flash between slip rings.

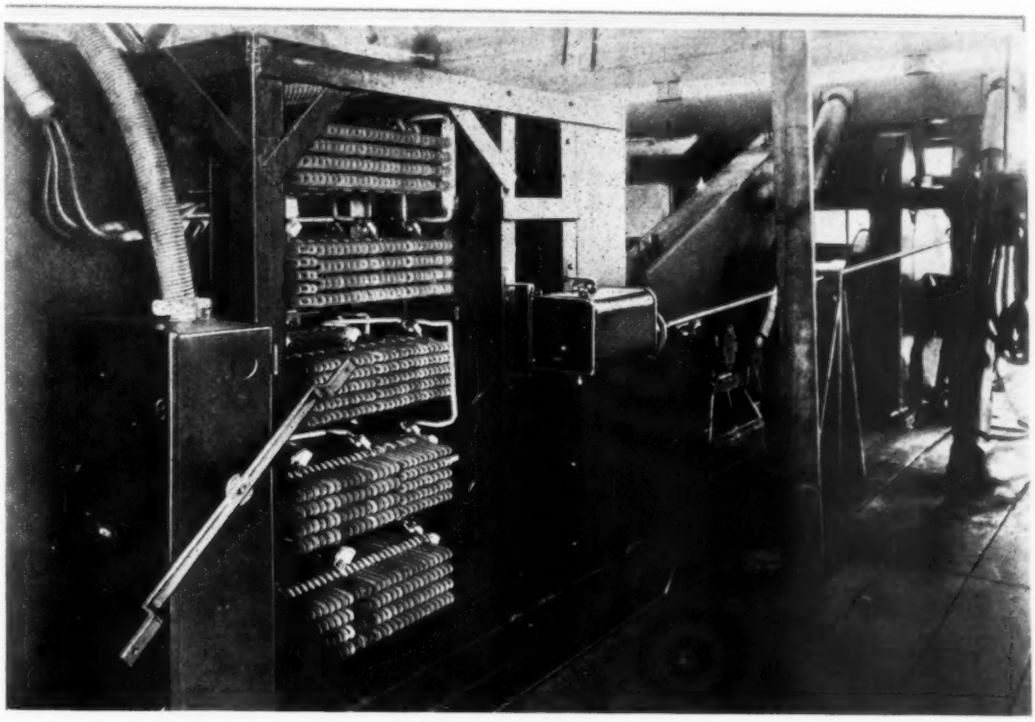
Clearance between rotor and stator should be checked

DRILLING EQUIPMENT

C. BARDE

occasionally, as this considerably affects the motor efficiency. Most motors are provided with adjustment screws in the bottom of the end bell, others in the bearings themselves. A small turn will compensate for wear of bearings. Clearance and bearings should be checked by a machinist or electrician on each new location.

When a motor heats it is likely due to a loose or dirty connection, low voltage, hot bearings or over-load. Occasionally, when pumps are located 100 to 150 feet from the controls, the motor heats. This usually is caused by low voltage, as the line loss due to heavy consumption of current causes a corresponding drop in voltage. In order to get the required horsepower the current must be increased, causing more heat and more loss. It is best to put the motor and pumps as close to the controls and source of power as possible, and to use a conductor of sufficient size to carry 20 per cent overload, especially on long leads. Any motor will heat excessively when operated at full rate load or over-load if voltage drops below normal rate for which motor was designed. If voltage is too high there is danger of causing a breakdown of secondary rotor of motor, but it is best to operate motor at five to ten per cent above its rated voltage than to operate below that point.



Control for 250/85-H. P. protected type drilling motor on a well at Oklahoma City.

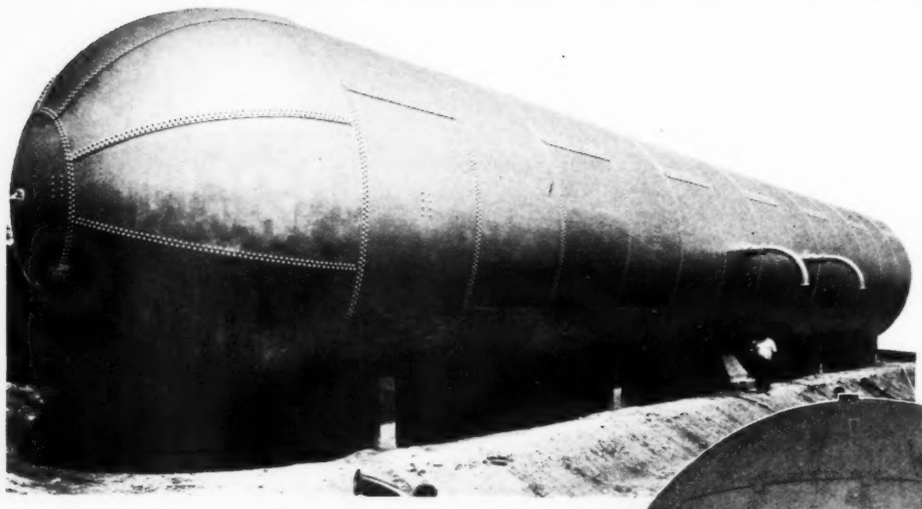
Most electric rigs are temporary and usually very little attention is given to clean and good connections, especially where service wires are connected to company lines. Most of these connections are poorly made, without use of solder; therefore, it is best to use a good line clamp or connector, easy to connect or disconnect, to obtain a perfect condition. The clamp requires very little time for either operation, and insures against any loss of voltage due to loose or faulty connections.

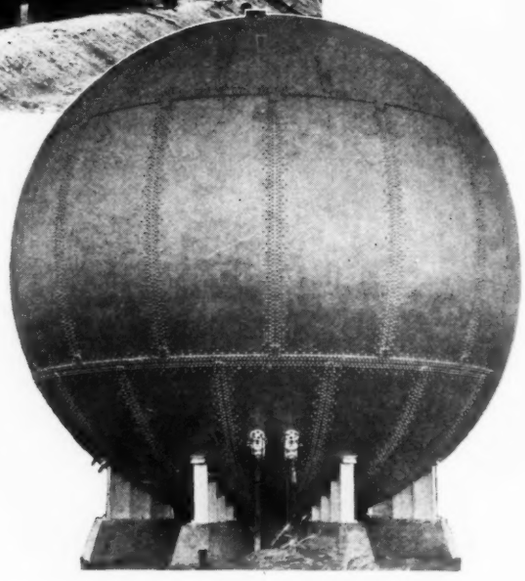
The controllers are the "brains" of the equipment. There are two types: Magnetic (or remote) and manually-operated. These are divided into two classes: open (air brake), and closed (immersed in oil). The magnetic control is operated by a master drum type controller, to which a throttle rod is attached. It needs only semi-annual inspection for loose connections and sand contacts and the application of a small amount of vasoline as lubricant. The magnetic contactors carry both primary and secondary current, and require a little more attention. Whenever extremely pitted or burned, they should be dressed down very carefully, as poorly dressed contacts burn away faster and give poorer contact than before dressing. New contacts, which can be purchased at very small cost, increase efficiency and reduce hazards due to contacts sticking or single phasing of motor. It is unnecessary to remove all pits, as some are very deep and contacts are usually large enough to compensate for the decrease in area caused by pitting. Usually each secondary contactor has three contacts, all of which should be made to break at the same time. This retards burning, especially on the forward and reverse primary contactors.

The oil-immersed contacts and contactors are also maintained the same as magnetic or manual operated controllers, only the oil used in tanks must comply with manufacturers' specifications. The tank should be kept clean and free from moisture or foreign matter, as either will weaken the insulating qualities of the oil. Oil should be drained and filtered at beginning of each new location or well, and it should be ascertained that the oil is at its proper level at all times.

As a summary, it is impossible to emphasize the value of keeping both motors and controls clean and every nut and bolt tight, as a very large percentage of shorts and burnouts are due to a loose connection, dirt or moisture, and those operators who have realized this point and have placed a responsible man in the capacity to accomplish this end, have lowered by a great percentage their maintenance cost on electrical drilling apparatus.

PITTSBURGH DES MOINES





Gas Holders ..*and*.. Pressure Spheres

To secure a better idea of its size, compare this big gas holder with the man's figure standing midway of its length of 110 feet.

This "Pittsburgh-Des Moines" holder was completed (including painting and final test) in April, 1931, for the City of Richmond, Virginia. Its diameter is 20 feet.

At the right is shown a "Pittsburgh-Des Moines" pressure sphere erected for the Iowa Railway and Light Corporation at Ames, Iowa. Its diameter is 40 feet. Note the specially constructed concrete foundations and steel supports.

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Applying Creep Stresses to Oil Still Tubes . . .

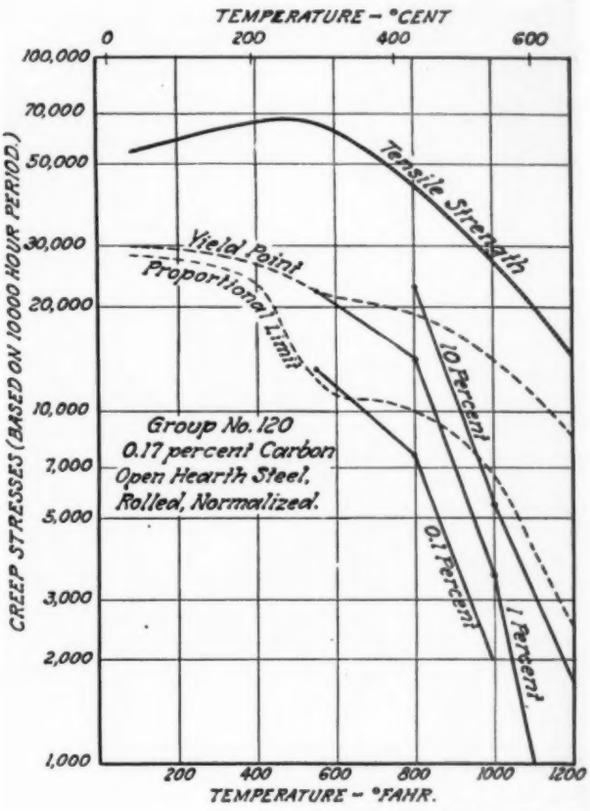
By

ROGER STUART BROWN*

RECENTLY an abundance of information on limiting creep stresses at high temperatures has been published. This has proved of material value to designing engineers, especially as it relates to the patterning of still parts. Although temperatures of metal are easily obtained and reasonably constant, special considerations enter into the application of stresses to still tubes and tube supports. The writer offers a few thoughts, based on some six years' close observation, on the manner in which available data should be used.

In the first place, before we can apply allowable stresses at high temperature, it is necessary to know the metal temperature, the determination of which, in the case of tubes and supports, is not a simple matter.

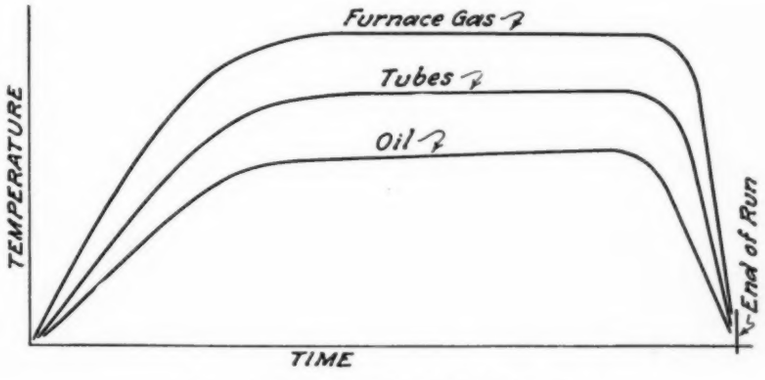
At the outset, with a clean tube, the tube wall temperature will be within 100 degrees of the oil temperature, even though the furnace and gas temperatures may be 400 to 600 degrees F. higher, due to the much greater transfer per-degree-per-square-foot-per-hour between oil and metal than between the furnace gas and the tube wall. Most operators will remove a swollen tube if its outside diameter has increased as much as one per cent. If the foregoing were the only condition, still tubes would last as long as 15 years, as most of them operate at stresses that will not result in one per cent creep in 100,000 hours at 1000 degrees F., being about the operating temperature of a tube wall with oil of 900 degrees F. inside. Yet tubes will sometimes burst after a few months' service, even when they are not corroded.



—Courtesy of Valve World.

Stress-temperature curves for "long-time" and "short-time" tensile tests plotted with logarithmic stress ordinate.

As coke deposit forms, it acts as an insulator between the tube wall and the cooling oil inside. Thus the tube wall temperature increases until, with a very heavy coke layer, it is considerably closer to the surrounding furnace gas temperature than to the oil. Unless the temperature of the surrounding gases or radiant heat has been strictly limited, failure will shortly occur. When it has been limited to a matter of only 200 degrees higher than the normal operating temperature of the tube wall, failure will occur in a relatively short time.



Curves showing temperature changes in furnace.

A concrete example will make this clearer: Say a cracking still embodies a tube, 4 inches O. D., 3 inches I. D. and the hottest oil tubes—those most likely to coke carry 800 pounds per square inch pressure. There is some disagreement among engineers as to how best to figure stress in a tube. The simplest formula is quite accurate for a thin-walled tube, and is

$$\text{Stress} = \frac{\text{I. D. of tube} \times \text{pressure}}{2 \times \text{thickness}} = \frac{3 \text{ in.} \times 800 \text{ lbs. per sq. in.}}{2 \times .5 \text{ in. thick}} = 2{,}400 \text{ lbs. per sq.in.}$$

This formula presupposes uniform distribution of stress throughout the cross-section of the wall. For elastic conditions with heavy pressures and thick walls this is not strictly correct, the stress at the inside diameter being greater than the average. To take account of this, either Lame's or Clavererino's formula is used. The author prefers the latter, which is:

$$\text{Stress} = \frac{\text{Pressure}}{3} \times \frac{(r^2 + 4 \times R^2)}{R^2 - r^2} = \frac{800 \text{ lbs.}}{3} \times \frac{(1.5^2 + 4 \times 2^2)}{2^2 - 1.5^2} = 2{,}780 \text{ lbs. per. sq. in.}$$

It will be observed that there is not a serious error in

* Engineer The Calorizing Co., Chicago.

using the simpler formula, and since failure under still conditions is due to semi-plastic flow, it seems reasonable to suppose that stresses would be equalized throughout.

Determination of the metal temperature is a complicated matter. Experimentation has been carried out with the pyrometer couples directly in the tube wall, but unfortunately this usually gives only the normal operating temperature which does not cause failure, and it would be a stroke of great luck if the location of the couples coincided with that of the heaviest coke deposit. Let us see what the life of the tube will be under various temperatures to which it is likely to be subjected. If the oil is 850 degrees F., the wall temperature, when the tube is clean, will be about 950 degrees F. If the 4-inch O. D. increases to 4.040-inch, a bulge will be noticeable and likely cut out by the careful operator. Therefore, the time required to produce this one per cent creep at various temperatures is given below. Values taken from recent creep stress determinations on .17 carbon open hearth steel, rolled normalized as reported by J. J. Canter and L. W. Spring of the Crane Co. and published in Fig. 17 of their article in the December (1930) issue of *Valve World*.

950° F.—1% in 100,000 hours (11.4 years)
1050° F.—1% in 10,000 hours (1.15 years)
1100° F.—1% in 1,000 hours (41 days)
1200° F. Rapidly—Proportional Limit of Material.

As long as this tube is clean, or only slightly coked, it will last a reasonable length of time, but if the temperature rises to 1100 degrees F., as it will when there is a heavy coke deposit, life of the tube will be terminated quickly.

Figures on relative life show the absolute necessity of limiting maximum temperatures to which the tube is exposed. In the still we have in mind, this is done by shielding completely from radiant heat the hottest oil tubes and exposing them to furnace gases which have not only given up much of their heat by radiation, but have been reduced to 1200 to 1300 degrees F. by their having been passed through several rows of the cracking bank carrying cooler oil. Even with these precautions it is necessary to shut down when coking has caused apparent red spots.

Reducing the stress to one-quarter of that cited in the foregoing example will increase by a matter of only 150 degrees F. the maximum temperature to which the tube can be subjected without rapid failure. Unfortunately, in stills employing pressures of 750 to 1200 pounds, the tubes are not placed where they are shielded from the hottest gases nor, in some cases, from the radiant heat. One case comes to mind, however, of a still operating under 165 pounds transfer pressure, 4-inch O. D., 3¼-inch I. D. tubes (stress 750 lbs. per sq. in.), where the circulation is straight counterflow to the furnace gases and the hottest tubes are exposed to gases at 1450 degrees F. as well as to the radiancy of the roof. In this case shutdowns were never made for hot spots and in three years there were no failures on stream in six units. In another refinery, however, using the same design of still, identical oil temperature (850-900 degrees F.), and tubes of the same size, but permitting a greater throughput and a furnace temperature of 1575 degrees F., tubes failed by bursting, and the average life was much less.

Swollen still tube.

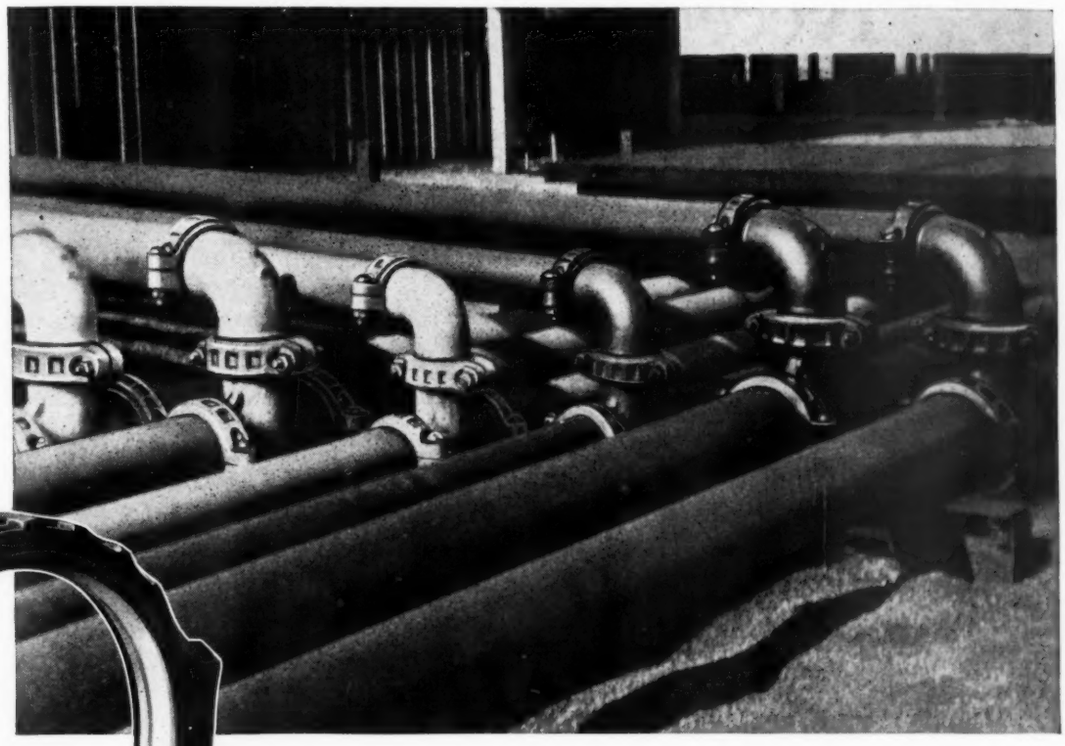
The austenitic chromium-nickel steels have great strength at high temperatures but, with properly designed furnaces limiting the maximum temperatures to which the tube can be subjected, very satisfactory results can be obtained from low or medium carbon steel. However, an alloy steel may also be used with excellent results.

The foregoing is based upon non-corrosive conditions and considered from the strength standpoint only. When high sulphur is present in either the fuel or the charging stock, use of corrosion-resisting metals such as calorized steel or the austenitic chrome-nickel alloys are of course indicated, provided corrosion is rapid enough to justify the increased investment.

When stresses in the tube are very low and the temperatures high, another kind of failure is encountered. Long exposure to furnace gases above 1100 degrees F. will cause oxidization of the outside of the tube. This occurs in re-run tubes of stills handling charging stock with high B. S., crude stills handling oil with large amounts of salt, or charging stock containing lime added to neutralize appreciable amounts of sulphur—in other words, conditions producing heavy deposits in the tube, unaccompanied by great pressure. One remedy is calorizing of the tubes. This process provides an iron aluminum alloy at the surface with a thin film of adherent aluminum oxide on the outside to protect the underlying metal from oxidization, giving protection practically indefinitely at temperatures not exceeding 1200 to 1300 degrees F., and even as high as 1650 degrees F.

When scale at the time of failure is only 3/32-inch to 1/8-inch thick on a 3/8-inch to ½-inch wall, it is not the primary cause of failure. Rather, failure may be attributed, for the most part, to creep caused by excessive pressure. Applying a surface protection under such conditions is useless—the remedy is first to reduce the stress by thickening the wall, or protecting the tube from maximum temperature. Then the tube will not burst by creep stress and the calorizing will protect it from burning through.

"For every joint on the line"



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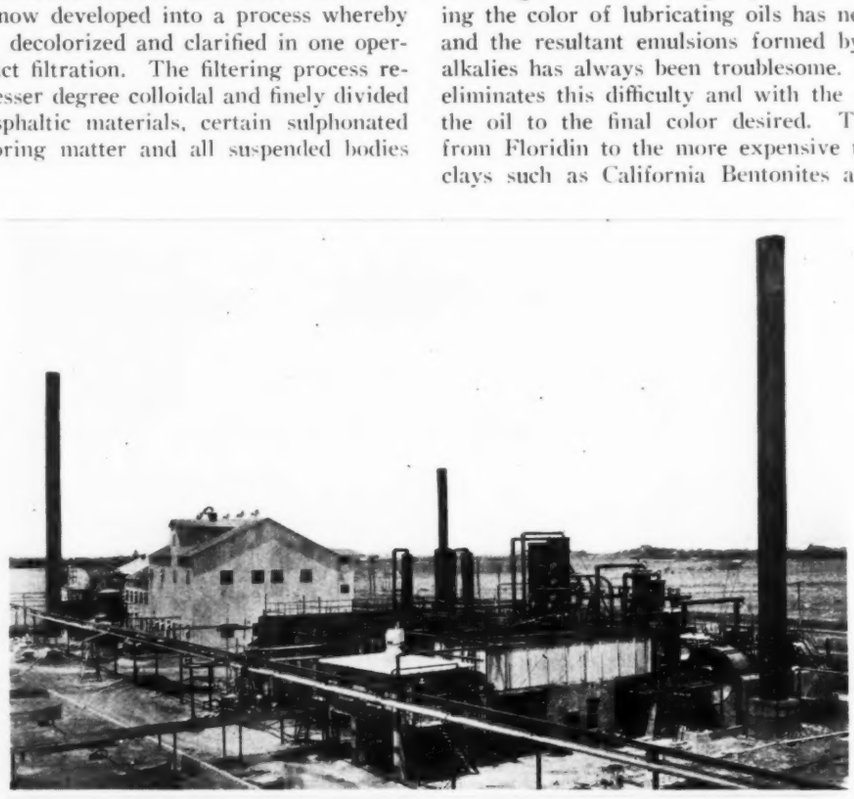
Recent Developments In Contact Filtration

By GEO. PFAU, *Supt., and* C. A. BARRERE, *Asst. Supt.**

FROM the beginning of the lubricating oil industry, it has been common practice to filter this product and, while in the beginning it was primarily a clarifying process, making use of bone charcoal or Fuller's Earth as an adsorbent, it has now developed into a process whereby the oil is neutralized, decolorized and clarified in one operation known as contact filtration. The filtering process removes to a more or lesser degree colloidal and finely divided carbon, tarry and asphaltic materials, certain sulphonated bodies, dissolved coloring matter and all suspended bodies and moisture.

The original filtering process made use of a vertical type of filter; varying in diameter from 6 to 12 feet and from 12 to 30 feet high. This was provided at the bottom with a perforated plate for drainage and covered with a blanket to hold the clay. It was also equipped with manholes at the top and on the side near the bottom for charging and discharging the material, used as a filtering medium. The filtration was carried out either by gravity or pressure feed. When the charge of clay was exhausted, as determined by the fact that the oil no longer would show an improvement in color, the operation was stopped, the oil was washed out with naphtha and the clay was steamed until all traces of naphtha were removed. The filter clay was then dumped onto conveyors and the earth conveyed to kilns of a suitable type, where the earth was revivified by burning at temperatures ranging from 600 degrees F. to 1200 degrees F.



View of Texas Pacific Coal & Oil Co. refinery showing contact plant (at left).

Fuller's Earth is the most widely used of all adsorbents in the percolation process, and the greatest percentage of it is mined in Florida and Georgia.

Several contact filtration systems have been worked out, each one peculiar to the kind of clay used. Most theories consider the capillary surface of the clay as the most important factor in determining the decolorizing value of the material, yet this alone will not suffice. It is generally accepted that it is clearly a problem in the field of colloid chemistry, and this is not as yet a highly developed branch of the science.

One of the decided advantages found by experimenters was the neutralizing effect of contact clays when applied to acidulated heated oils. The efficiency of sulphuric acid as an agent for removing objectionable bodies and improving the color of lubricating oils has never been questioned, and the resultant emulsions formed by neutralization with alkalies has always been troublesome. The contact method eliminates this difficulty and with the one operation brings the oil to the final color desired. The clays used range from Floridin to the more expensive treated and synthetic clays such as California Bentonites and Montmorillonites.

The contact process consists briefly of mixing finely ground clay (90 per cent through 200 mesh) with the oil, which may be an acid treated oil, and heating the mixture to the temperature necessary for the maximum efficiency; and then separating the oil and clay by means of a filter press. Thus where an acid oil is used, the decolorization and neutralization take place simultaneously.

There are two types of contact clays in use, first, the finely ground raw or mined clay, and, second, clays that have been acid treated to improve their efficiency. As a rule, sulfuric acid is used for the treatment. Due to the high cost of the acid treatment of the clay and the investment required for such treatment, the treated clays are considerably more expensive than the raw clays, but this is compensated for by the increased efficiency of the clay; since the adsorptive value of the clay may be increased from two to five times over that of the raw clay.

As a rule, raw clays have a higher neutralization value than the treated clays, but on the other hand, their decolorization value is comparatively low; and this may be due to both impurities contained therein and restricted surface of the adsorbent. Each particular clay is an individual problem, in respect to its adaptability for the particular oil under treatment.

Treated clays may be used in two forms, either as a pulp, which must be prepared at the point that it is used; or in the dried form, and in either case, the treatment of the

* Texas Pacific Coal & Oil Co.

raw clay is similar. However, if used dry, the acid treated clay must be dried and then reground. Also in using a dried clay, whether raw or treated, water or steam is necessary in the contact operation in order to give the maximum efficiency. Steam may increase this efficiency as much as 20 per cent as it helps remove the free acid and also enlarges the active surface of the clay, by aiding in the suspension of the clay in the oil. Steam is unnecessary where the clay is used in mud or pulp form because of the water contained in the pulp.

The chemical analysis of a clay is not a satisfactory criterion for its decolorizing value. Two clays of practically the same chemical analysis may show radically different results as regards their filtration values. The determination of the efficiency of a clay for contacting purposes must be gone into very thoroughly by actual decolorization tests in the laboratory before it can be definitely accepted or rejected for contacting purposes. Much experimentation is necessary to arrive at the best concentration of acid that should be used in the treating solution. In several cases the efficiency of a clay under examination was increased by using a very weak concentration of acid, while the best efficiencies on the other clays were obtained with fairly strong acid concentration. Also the amount of treating solution, if varied appreciably, has a marked effect upon the yield and efficiency of the finished clay. It has also been noticed that the efficiency of the finished clay will vary as much as 25 per cent using the same oil, depending upon the degree of refinement obtained in the acid treatment.

As the success of the contacting process is more or less dependent on the adsorptive area of the clay, it follows that with any type of clay used, the maximum fineness must be had, and on some raw clays this runs as high as 99 per cent through a 200 mesh screen. However, where the clay is to be acid treated and used as a pulp such fineness is not necessary, as the cooking operation disintegrates the particles to the colloidal size which is much finer than could be obtained by grinding.

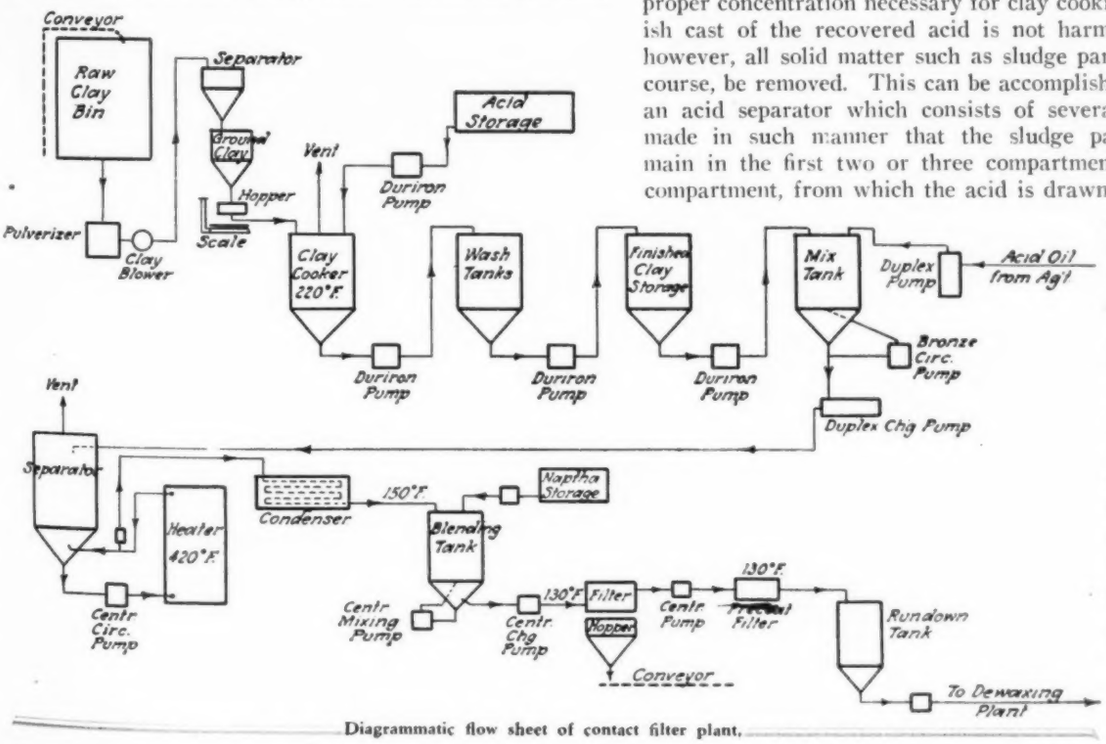
The decolorizing action generally increases with an increase in temperature, some clays reaching their maximum efficiency at 600 degrees F. The usual contacting range is from 400 degrees F. to 500 degrees F. However, the same results could be obtained at lower temperatures by increasing the time of contact between the clay and the oil. A closed continuous system is used as the hot oil should never be exposed to air. This article will deal with the contact processes wherein the clay is used in the pulp form.

Preparation of the Clay for Treatment

The raw clay which is to be acid treated is generally received in lumps varying from 1 to 2 inches in diameter. It is ground by means of a hammer or roller mill so that at least 75 per cent goes through a 200-mesh screen. From the mill, the clay is discharged to the ground clay storage bin. It should be noted that if the clay contains moisture in appreciable quantities difficulty will be encountered in grinding the clay.

From the storage bin, the clay is charged to the acid cooker. The cooker is a lead-lined tank with a conical bottom; it should be insulated and supplied with air and open steam connections at the bottom. The cooker is charged with 50 per cent of the weight of the clay used (dry basis) of sulfuric acid diluted to a concentration of 20 per cent; due allowance being made for the moisture content of the clay, and the steam used in cooking. The acid solution is brought to boiling by means of the open steam, and the clay charged in small quantities upon the boiling acid. Agitation with air and steam is continued until all the clay has been charged to the cooker. Charging the clay slowly will prevent the formation of lumps which are difficult to break up. When all the clay is charged and the temperature reaches 220-230 degrees F., agitation should be discontinued and the mass allowed to digest for 12 hours. The finely divided clay particles will be well dispersed and remain in suspension without any further agitation throughout the cook.

Some clays will give higher efficiencies when acid concentrations of less than 20 per cent are used. It is seldom that concentrations above 25 per cent are used, as the pulp is so dense that intimate contact between the clay particles and acid is impossible. In this case some of the clay is under treated with a resulting loss in efficiency. Greater quantities of acid than mentioned above are also used. The loss of clay in acid treating ranges from 25 per cent to 40 per cent. Recovered acid obtained from acid sludge may be used for cooking the clay. The acid can be recovered in the proper concentration necessary for clay cooking. The greenish cast of the recovered acid is not harmful to the clay, however, all solid matter such as sludge particles should, of course, be removed. This can be accomplished by the use of an acid separator which consists of several compartments made in such manner that the sludge particles will remain in the first two or three compartments, and the last compartment, from which the acid is drawn, will be free of sludge. Considerable saving in fresh acid for clay treatment can be effected by the use of recovered acid. The acid treatment removes the aluminum and other impurities, forming soluble sulphates, which after washing leaves the clay a honeycombed silicate almost colloidal in size,



Diagrammatic flow sheet of contact filter plant.

containing innumerable channels upon the surface of each particle.

After the acid treatment is completed, the clay pulp is transferred to the wash tanks, using a pump of acid-resisting material. It is washed with water to remove the unused acid and soluble acid salts. The clay must be washed thoroughly. The acidity on the finished pulp should not be over 3 mg. of KOH per gm. Hot or cold water may be used for washing; however, best results are obtained by using water at a temperature of 150 degrees F., as it will shorten the settling time necessary. Lead-lined tanks or pine stave tanks with conical bottoms should be used for washing. The pulp should be agitated with the wash water for 20 minutes and allowed to settle, and then drawing off the wash water. The settling and drawing off process will require from 6 to 8 hours. This procedure is repeated until the pulp is at the desired acidity and usually requires three washes. The pulp now contains about 25 per cent solids and is transferred to the storage tank ready for use in that form. The time required for the preparation of a batch of clay is 36 hours.

The desired amount of pulp is added to the acid oil, and this mixture agitated by means of a cyclone type stirrer or circulated by a pump. From two-tenths to two lbs. of clay per gallon of oil is used. The mixing tanks should be in duplicate so that one tank can be prepared while the other is being charged to the contact still. The tanks are lead-lined and have conical bottoms. One to two hours' mixing will insure a thoroughly mixed batch.

The clay pulp and acid oil is then pumped to the pipe still separator where the water from the clay pulp is flashed off. Suction is taken from the separator and the clay and oil mixture pumped through the tube still, heated to 400-420 degrees F., and discharged back to the separator. A continuous stream is drawn from this return line equal to that charged to the separator from the mixing tank. The oil drawn off is then pumped through a cooler to the press charging tank.

Generally the filtering operation is carried out in a dilute solution, by diluting the oil with 50 per cent naphtha. The naphtha used should have a boiling point of not lower than 180 degrees and an end point of 400 degrees F., so that losses may be kept at a minimum.

A leaf type filter operating at 50 pounds pressure is used to effect the separation of the spent clay and clear filtrate. The leaves of the press should be covered with monel metal cloth, due to the acidity of the clay. One-inch to 1½-inch coke thickness is built on the leaves and filtering discontinued. The press is then drained and the cake washed with naphtha until the filtrate is clear then blown with air to remove as much naphtha as possible. The press is then dumped and another cycle begun. The filtrate will still contain a small quantity of fine clay which passed through the leaves of the press before a layer of clay, which acts as the filter medium is built on the leaves. This leakage of clay can be reduced to a minimum by allowing the first filtrate to go back to the feed tank until a layer of clay is built on the leaves. This cuts down the thruput per cycle and does not completely eliminate the trouble. One solution is to pass the filtrate through another press of a smaller size that has the leaves precoated with some suitable type of filter aid. This fine clay must be removed, otherwise the coloring matter retained in the clay will be leached out and darken the finished oil. It will also cause a bad emulsion test on the finished product. Trouble will also be caused by these fine particles in the centrifuge plant, where they will be collected under the ring dam of the centrifugals and thus retard the dewaxing operation. One of the most notable differences between natural clays and treated clays may be observed on the press, due to type of filter cake. Natural or raw clays form a more porous cake which results in higher filtrates and the treated clays form much denser cakes. However, due to the smaller quantities of treated clay necessary longer filter cycles are generally obtained, which increases the over-all filtration rates and so overcomes the lower rates of actual flow.

The greatest advantage of contact filtration is in all probability the fact that the desired color of the oil can be controlled from the beginning to the last of the filter cycle, thus eliminating the necessity of blending darker stocks with the lighter color stocks to produce the desired color. This naturally gives a more uniform quality of oil. The second big advantage is the elimination of the neutralization troubles, so frequent in acid treatment.

Other distinct advantages are more flexible operation, low first cost, simplicity of operation and more accurate control of operations. The lubricating oils produced by this process show exceptionally good tests as regards emulsion, corrosion, color and carbon residue, all of which are a measure of the refinement the oil has undergone.

Much work has been done upon the revivification of contact clays. Fine clays have been reclaimed by burning at 750 degrees F. to 1000 degrees F., with efficiencies as high as 90 per cent of the original efficiency, with small burning losses. Recovery by use of various solvents has also been successful. Thus the expensive procedure of discarding the clay after being used once has been eliminated.

Corrosion and erosion are most active in the clay cooker, transfer lines from the cooker to the wash tanks, suction and discharge lines from the mixing tanks to the pipe still separator and the vapor space in the top of the separator. The corrosion is due to weak sulfuric acid, sulphur dioxide and tri-oxide, and the acid oil itself. The cooker should be lead-lined, which will eliminate all corrosion. All transfer lines, swinging lines, sewer lines and fittings should be fabricated of non-ferrous alloy, or a good quality cast iron.

Pumps used in transferring the clay pulp should be acid resistant. Material should resist both erosion and corrosion. Strainers should be placed in the suction line of the pumps to avoid abrasive materials entering the pump and breaking the case. Cracked impellers should be removed and the packing should be loose. Strains should be avoided as this condition will break the sleeves.

Once the oil and clay mixture has been contacted, very little corrosion will be evident; however, erosion takes its place. After contacting, the clay becomes hard and brittle. Pumps handling the contacted clay and oil mixture should be fabricated of special metal.

The vapor space above the oil level in the separator is corroded by the weak sulfuric acid removed by the steam. Attempts have been made, with some degree of success, in spraying the inside of the separator with a thin layer of acid-proof cement. The mixing tanks should be lead-lined. The wash tanks should be either lead-lined or made of wood; such as pine or California fir. There is no evidence of corrosion in the pipe still headers or tubes, and very little erosion.

Various acid-proof non-soluble paints have been used to combat corrosion wherever possible. Nitro-cellulose lacquers have been found suitable for the purpose.

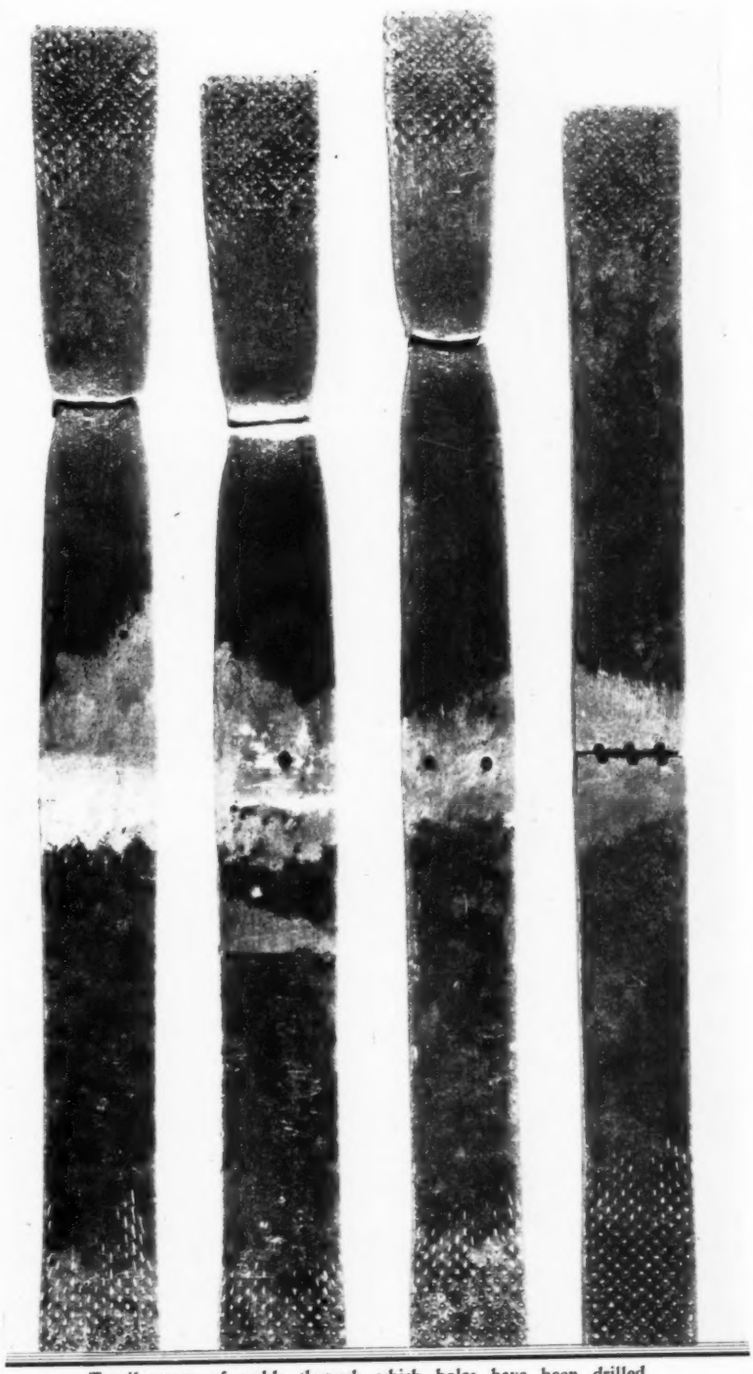
Strong acid fumes, due to the acid oil or sulphuric acid, such as in the clay cooker, may be eliminated by using jets made of acid-proof material wherever this nuisance is present. With the use of these, there will be no evidence of acid present at any part of the contact plant.

If the proper materials are used in the construction of a contact plant, the maintenance cost, due to corrosion or erosion will be very small.

Shield Welded Pressure Vessels Now Safe For All Hazardous Uses

By G. RAYMOND*

OF much importance to the petroleum industry are the recent remarkable improvements in the art of electric arc welding known collectively as Shielded Welding Processes. By means of these greatly advanced welding processes, joints of nearly 100 per cent efficiency can be rapidly formed between parts of almost any thickness or shape. They are making economical the welding of formed plates into pressure vessels which, in behavior, compare well with vessels forged from single ingots. Their safety is most forcibly attested by the recent action of the Boiler Code Committee of the American Society of Mechanical Engineers. This properly conservative body now proposes for the first time specifications under which fusion welding may be used for pressure vessels without limit as to size, thickness or use.



Tensile tests of welds through which holes have been drilled demonstrate excess strength of joint.

That it is now possible to overcome this brittleness, the Boiler Code Committee recognizes in the December, 1930, issue of Mechanical Engineering, the monthly journal published by the American Society of Mechanical Engineers where appears: "Proposed Specifications for Fusion Welding of Unfired Pressure Vessels." From this Specification two significant sentences are quoted: "All joints in vessels covered by this Code and of any dimensions may be fusion welded provided that in addition to meeting the requirements for material and design, they will conform to the following specifications, based on those which have been published under the heading, 'Proposed Specifications for Fusion Welding of Drums or Shells of Power Boilers.'"

"The Committee is also considering the classification of pressure vessels and should a classification be adopted, these specifications are primarily intended to cover the class of vessels demanding the highest type of construction."

In the March, 1931, issue of the same Journal is published an article entitled, "Proposed Specifications for Fusion Welding." From this specification the following interesting paragraphs are extracted:

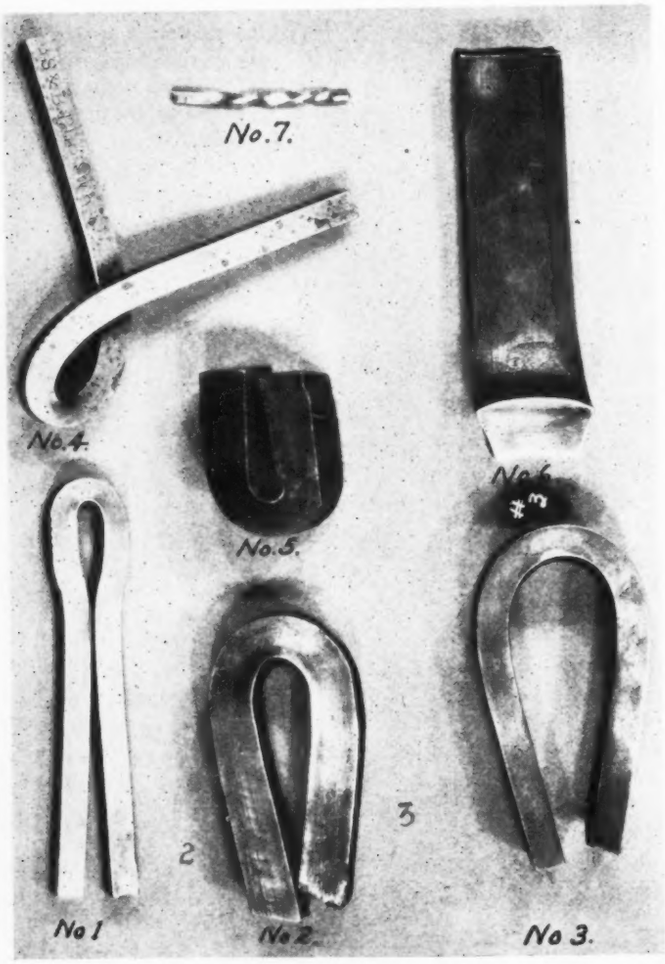
"The following proposed revisions, which are now under the joint consideration of the American Welding Society and the Boiler Code Committee, are for embodiment in the code for unfired pressure vessels and for embodiment in the code for power boilers."

"Pressure vessels may be fabricated by means of fusion welding provided the construction is in accordance with the requirements for material and design as required by this code and the fusion welding process used conforms to the specifications for the grade of welding indicated for each class of vessel."

* V. P. American Tank & Equipment Corp., Oklahoma City, a subsidiary of Black, Sivalls & Bryson, Inc.

"Fusion-welded pressure vessels shall be classified according to the following schedule. The grade of welding required for each class shall be as indicated.

"Class 1. All vessels covered by this code, constructed in accordance with the rules for this class, may be used for any purpose. This class includes vessels containing noxious, poisonous, or inflammable liquids or gases. These vessels shall be welded with Grade "A" Welding. The allowable working stress shall be 18 per cent (1/5 of 90 per cent) of the minimum of the specified tensile range of the plate used.



Bend tests demonstrate remarkable ductility and toughness of BS&B Flexwelds.

No. 1—½" Plate 62½% elongation of weld.
No. 2—⅞" Plate 53% elongation.
No. 3—⅞" Plate 30% elongation—this is proposed boiler code.
No. 4—½" Plate required for Class 1 welded vessels.
No. 5—⅞" Plate 60% elongation.
No. 6—Polished cross section of weld shows homogeniety.
No. 7—Twist made entirely from weld metal.

"Class 2. All vessels covered by this code are included in this class, excepting those containing noxious or poisonous gases or liquids, provided the plate thickness does not exceed 1¼ inches. These vessels may be welded with either Grade "B" or Grade "C" welding. When Grade "B" welding is used, the allowable stress shall be 16 per cent (1/5 of 80 per cent) of the minimum of the specified tensile range of the plate used. When Grade "C" welding is used, the allowable stress shall be 14 per cent (1/5 of 70 per cent) of the minimum of the specified tensile range of the plate used.

"Class 3. All vessels covered by this code not exceeding ⅜-inch plate thickness and used for the storage of gases or liquids at temperatures not exceeding their boiling temperatures at atmospheric pressure, may be included in this class, except those containing noxious, poisonous, or inflammable liquids or gases. These vessels may be welded with Grade "D" welding. The allowable working stress shall be 12 per cent (1/5 of 60 per cent) of the minimum of the specified tensile range of the plate used for butt joints, and 10 per cent (1/5 of 50 per cent) for double-fillet welded lap joints.

"The allowable working stresses on the joints in pounds per square inch for different temperatures are given in Table 1."

Please note that no restriction as to size, thickness or use is placed upon fusion welded vessels when constructed according to Class 1 of these specifications. From Class 2 construction are restricted only to those greater than 1¼-inch in thickness or those containing noxious or poisonous liquids or gases.

These specifications go on to cover in detail a thoroughgoing set of tests intended to show forth completely the results of the welding work. They include tensile tests and bend tests of the welded joint, tensile and specific gravity tests of the weld metal, hydrostatic and X-ray tests of the completed vessel. Stress relieving, qualification of welders, qualification of process, and of course quality of plate material, are also covered. Full discussion of these proposed specifications has been invited of all interested. The particular co-operation of the oil industry has been solicited by visits from Mr. C. W. Obert, Honorary Secretary of the boiler code committee, to the Mid-Continent and other oil fields.

It is not the purpose of this article to enter into a discussion of the details of these specifications, except to point out that their working stress allowances are considerably more conservative than those now generally used in many branches of the oil industry. These specifications are mentioned here because they are most convincing proof of the advances which have been accomplished in the welding art.

No restriction is made in them as to the type or kind of welding technique which shall be employed. The term fusion welding which they use throughout will apply to any kind of acetylene or electric arc welding. However, their requirements as to ductility, strength and homogeneity of the deposited weld metal are so exacting, particularly in the first and second classes in which most petroleum equipment will fall, that it is safe to say they can at present be satisfied only by the new shielded arc welding processes or possibly by the acetylene welding process.

The details of these shielded arc welding processes are for the most part the carefully guarded secrets of the companies which have developed them. However, they all possess one common characteristic which is the keynote of their success:

The welding must be accomplished in a neutral or reducing atmosphere rather than in an oxidizing atmosphere.

Although it is easy to state the requirement that the weld must be accomplished in a neutral or reducing atmosphere, it has been very difficult to accomplish this. Years of painstaking research have been required to reduce the various methods to commercial success. It can be fairly stated that exacting control and regulation of all factors in the process—extremely careful technique—are prerequisite to success. The temperature of the arc at which the weld takes place is extremely high. The ever-present oxygen and nitrogen of the atmosphere are all too eager to work in and attack the iron at these extreme temperatures. It is no simple matter to keep them entirely out. Any reducing agent used is likely to become contaminated by the surrounding air. It is also likely to be dissolved into the steel,

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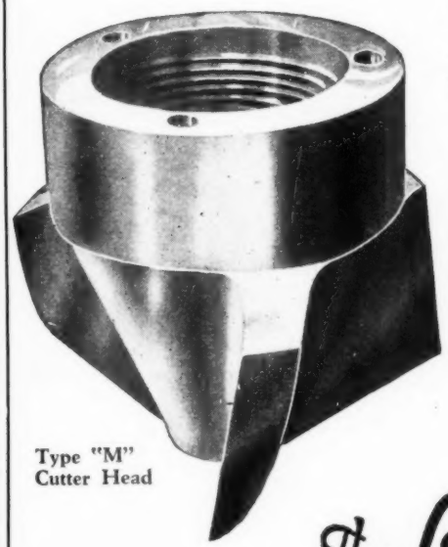

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later to form blow holes and porosity. Fluxes used are likely to become entrapped in the weld metal. There are other difficulties.

However, the rewards to be attained, once all conditions are properly controlled are most gratifying. The weld metal can be made stronger than the parts joined. This is illustrated by Photo. No. 4. Here holes have been drilled in the welded joint occurring at the center of these tensile test specimens after all excess weld metal has been machined off. These holes progressively weaken the weld until it breaks in the fourth test with three holes. The results of these tensile tests as set forth in Table No. 1 indicate that the strength of the weld metal was 77,000 pounds per square inch whereas the strength of the base plate averaged 55,233 pounds per square inch.

That this excess strength of the weld metal is attained without sacrificing ductility is demonstrated by the bend tests of photograph No. 5. These bend tests form one of the most sure and simple means of proving the character of the welds during the process of development. If fusion is not complete there will be failure along the side of the weld at an early stage in the bending. If there is slag, or other inclusion in the weld, the bend test will show it up all too readily. If the metal is inclined to be brittle, or to be porous, the bend will fail before the required elongation is secured and the resultant fracture will disclose the nature of the defect. Open arc welds can rarely be bent to 10 per cent elongation. The boiler code specifications propose an elongation of 30 per cent within the weld metal under free bend tests for their highest quality welding (Grade "A"). Elongations of 40 per cent to 50 per cent are readily attained.

The conditions in the welds of complete vessels may be somewhat different from those depicted by individual test specimens due to the temperature stresses set up by the welding operations, the heat of which is much greater under shield welding conditions than with the open arc. So although the tough ductile weld metal of the shield welded seam is incomparably better able to withstand these stresses, it is considered desirable in the case of most vessels, and imperative in the case of those whose walls are thick in proportion to their diameters, to relieve these temperature stresses by a low temperature annealing operation. In this operation the entire vessel is heated in a large annealing oven, photograph No. 6, to a uniform temperature of 1100 degrees Fahrenheit, a dull red heat just safely below the slagging point for thin-walled vessels, and allowed to cool slowly in still air.

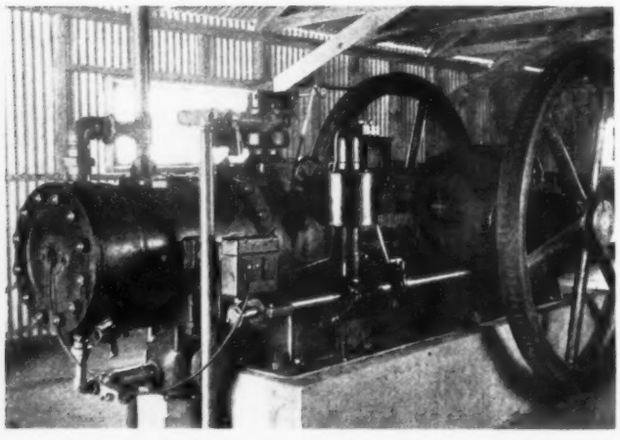
The proper careful preparation of the parts before welding is a prerequisite to the successful manufacture of these high quality pressure vessels. The importance of this preparation cannot be overlooked. The quality of the steel plate and other raw materials must be carefully controlled. The design must be correctly proportioned in all its details to guard against local concentrations of stresses. All edges for welding must be accurately machined so that they will fit straight and true upon assembly. The rolling and forming must be so carefully done that all parts will fit properly together without undue straining. In the routine of welding "cleanliness is next to godliness" toward securing perfect welds.

These processes have now been developed to the point that vessels so uniform in strength are being regularly built that for demonstration purposes, they can be stressed far beyond their elastic limit to the ultimate strength of the plate material. Whereupon, after due stretching, they are far more likely to fail in the plate than in the tough welds.

TABLE No. 1

Tensile tests of welds machined flush. Welds weakened by drilled holes to demonstrate excess strength of joint.

Sample No.	Width	Thickness	Holes	Ult. Strength	Stress in weld metal	Remarks	Elongation in weld metal	Reduction area in weld metal
1.	1.645	.490	None	57200 lb. sq. in.	57200	in plate		
2.	1.784	.495	$1\frac{3}{16}$x.495	55500 lb. sq. in.	62200	in plate	25%	
3.	1.650	.497	$2\frac{5}{32}$x.497	53000 lb. sq. in.	65150	in plate	24%	
4.	1.540	.495	$3\frac{5}{32}$x.495		77000	in weld	48%	22%



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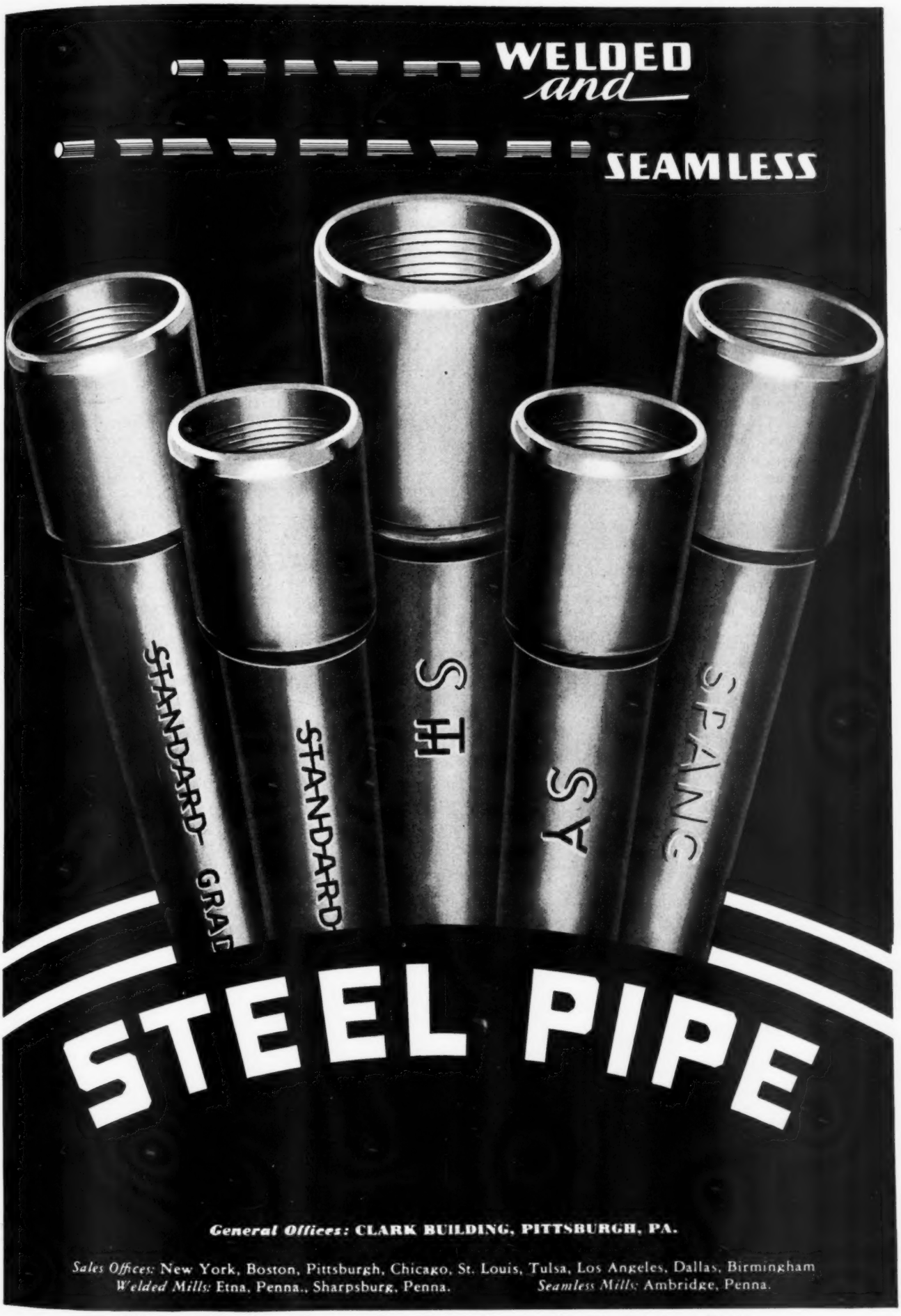
A TWO-CYCLE 40-horsepower engine has proven a very satisfactory pumping station prime mover for the Stanolind Oil & Gas Company in the Beebe, Okla., field.

The power operates a 24-inch band wheel by means of a belt, and at the present time is pumping six wells, all jack-equipped, but is built to accommodate other wells. The unit has been operating about a year.

The wells average from 2,500 to 2,600 feet in depth, and are tubed with 2-inch tubing. The average stroke is 30 inches or more. Several wells are being operated at a reduced pump strokeage per minute, to conform to proration orders.



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The WELL METHOD of PRODUCING OIL

By W. P. HASEMAN,
Consulting Petroleum Engineer, Oklahoma City, Okla.

AN oil well is essentially a machine. It consists of three parts: the well bore hole, the porous rock reservoir within the drainage distance and the compressed fluids contained therein. These parts are assembled into a working and producing mechanism.

The oil well mechanism, designed in part by man and in part by nature, is for the transference and transformation of the energy stored in the compressed fluids confined in the porous rock reservoir, to the production of oil. The efficiency of this transference and transformation of the energy to the production of oil depends upon two factors, the spacing of wells, and the conservation and utilization of the gas and energy in the reservoir. These factors are two of the most potent, if not the only, factors which regulate the method of control of the production of the well, the ultimate production of oil from the well, and the security of property rights to the common underground supply of oil, gas and energy.

The science of well spacing has been advanced by the Haseman spacing formula.* This formula is based upon the new conception which classifies a producing sand in accordance with the ability of the energy stored in the compressed and confined fluids to produce the oil from the sand into and out of the well with a set and standard distance between the wells.

A sand has a producing quality defined as "1", when, say, five per cent of all the oil confined in the rock reservoir is produced with a spacing of one well to each 10-acre tract. It has a producing quality, "2", when 10 per cent of the oil is produced with a spacing of one well to each 10-acre tract. Similarly, it has a quality, "3", when 15 per cent of the oil is produced with a spacing of one well to each 10-acre tract; a quality, "4", when 20 per cent of the oil is produced with a spacing of one well to each 10-acre tract; and a quality, "5", when 25 per cent of the oil is produced with a spacing of one well to each 10-acre tract.

It is evident with sands of any and all producing qualities that zero wells drilled to each 10-acre tract will produce zero per cent of the oil, while an infinite number of wells drilled to each 10-acre tract will not produce more than 100 per cent of the oil. The data on sands and production indicate that, in general, an infinite number of wells to each 10-acre tract will not produce much in excess of 50 per cent of the oil confined in the reservoir.

The producing relation of a sand of quality "2", for example, is determined in part by the limiting conditions, which are: (1) zero wells to each 10 acres will produce zero per cent of the oil; (2) one well to each 10 acres will produce 10 per cent of the oil, and (3) an infinite number of wells to each 10 acres will produce, say, 50 per cent of the oil. These three limiting conditions give three points in a plane. A continuous curve passing through these three points may be such as to pass through and contain the respective per cent of oil produced from the given sand at every intermediate point lying between the above defined points.

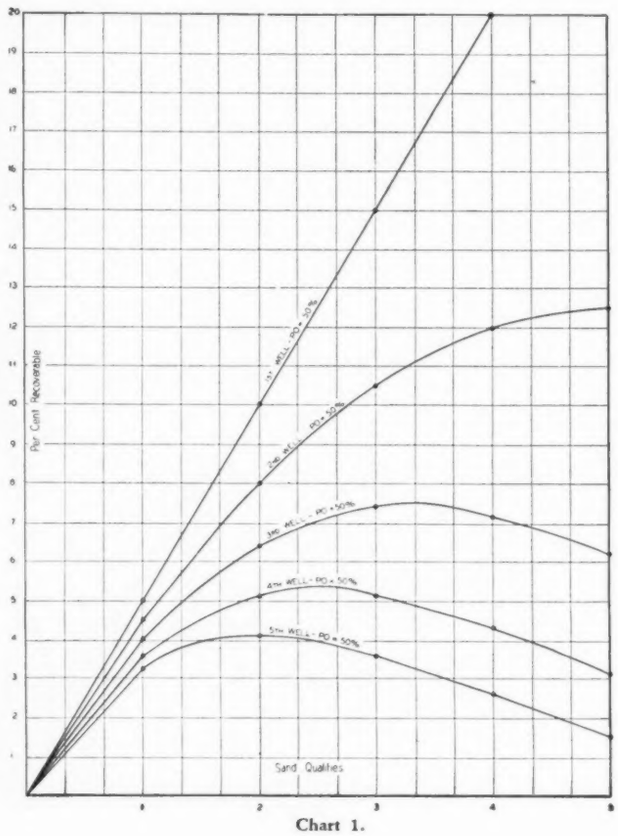

Chart 1.

The Haseman formula represents a type of curve which meets the conditions imposed at the three defined positions as well as the conditions imposed by actual field data at the intermediate positions. Certain computed data from the formula are shown graphically on Chart 1. Curve 1 on the chart defines the qualities of the sands and represents the per cent of the oil produced with a spacing of one well to each 10 acres from sands of qualities 1, 2, 3, 4, and 5. Curve 2 represents the added per cent of oil that would have been produced by the added and second well provided the spacing had comprised two wells to each 10 acres instead of one well. Similarly, curves 3, 4, and 5 represent the added per cent of oil that would have been produced by the added third, fourth and fifth well, respectively, provided the spacing had comprised three, four and five wells, respectively, to each 10 acres instead of one well.

The data on Chart 1 show that for a sand of quality "1" five per cent of the oil will be produced with a spacing of one well to each 10 acres, while with an unlimited increase in the number of wells to each 10 acres 50 per cent of the oil is available and will be produced. Therefore, with a spacing distance between the wells of 660 feet only 10 per cent of the available oil by wells will be produced from the sand. Similarly, with any given spacing distance between

*National Petroleum News, May 8, 1928.

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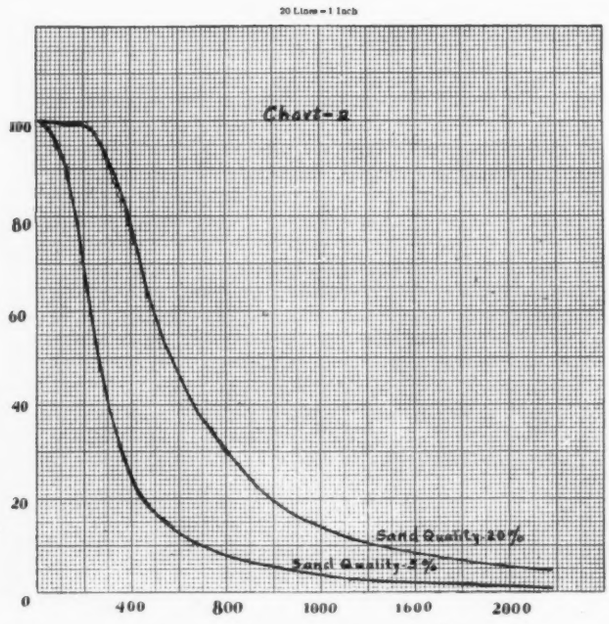


the wells and for a sand of any given quality, the per cent of the available oil by wells that will be produced can be determined. Such data are represented graphically on Chart 2 in curves 1 and 2 for sands of quality "1" and "4", respectively. Chart 2 reveals the following pertinent and obvious facts:

(1) That oil wells, which when spaced on an average property at a distance as close as 150 feet to each other in a well spacing pattern, will produce 85 to 99 per cent of all the oil possible to be produced by wells in any spacing whatsoever without the introduction of extraneous energy into the reservoir. This fact proves that the oil well mechanism is a physical thing with a minimum linear dimension and extent. The graphical representation of this fact is shown in the curves on the chart.

(2) That the magnitude of the interference of oil wells due to their proximity to each other decreases as the distance between them increases and is such that, in general, oil wells should not be located farther apart on an average property than 1,000 feet. Oil wells spaced at a greater distance than 1,000 feet will produce only five to 25 per cent of the ultimate oil possible to produce with a closer spacing of wells. This fact proves that the extent of the effective action of an oil well mechanism is not greater than 1,000 feet. The graphical representation of this fact is shown in the curves on the chart.

The conservation and utilization of the gas energy in the fluids with a given spacing of the wells will depend upon the method of operation of the wells. The proper method of operation of the wells requires certain knowledge of the well mechanism. Some data are available on the operating pressures and gas-oil ratios utilized by the well mechanism in the production of oil. There are also data on the ultimate production from wells and on the general character of the fluid flow and the rate of flow maintained by the well mechanism. These data have not been classified, interpreted and formulated into a simple and definite working rule for the operation of the well mechanism.

The well reservoir is known to release energy in establishing and maintaining the flow of oil and gas to and out of the well. The rate of release of this energy is here considered as directly proportional to the rates of release of oil and gas from the reservoir. The efficiency of the well mechanism in producing oil under these assumed conditions is taken as directly proportional to the height H of the lift and inversely proportional to the gas-oil ratio G. The efficiency of the well mechanism is further defined as 100 per cent when the energy spent by the well reservoir in lifting a barrel of oil vertically against gravity to a height H is equal to the energy released by the volume of gas which accompanies the barrel of oil and expands isothermally from a pressure of .34H to 15 pounds per square inch.

The above defined relations give certain gas volume and efficiency data for the operation of a hypothetical but more or less generalized well mechanism. The data will have a qualitative significance and a definite application to each well in a pool.

The application of the above determined efficiency data in the production of oil and gas will be illustrated by three examples:

Example 1: An oil pool with wells 2,000 feet deep and 680 pounds per square inch fluid pressure.

Example 2: An oil pool with wells 4,000 feet deep and 1,360 pounds per square inch fluid pressure.

Example 3: An oil pool with wells 6,000 feet deep and 2,040 pounds per square inch fluid pressure.

EXAMPLE 1

(1) The energy required to lift a barrel of oil (290 lb.) 2,000 feet is.....580,000 ft. lb.

(2) The energy of one cubic foot of gas expanded isothermally from a pressure of 680 to 15 lb. per square inch is.....8,240.4 ft. lb.

(3) The well efficiencies and gas volumes utilized are:

Efficiency Per Cent	Gas Volume Cu. Ft.
100	70
75	94
50	141
25	282
10	704
5	1,408
1	7,039

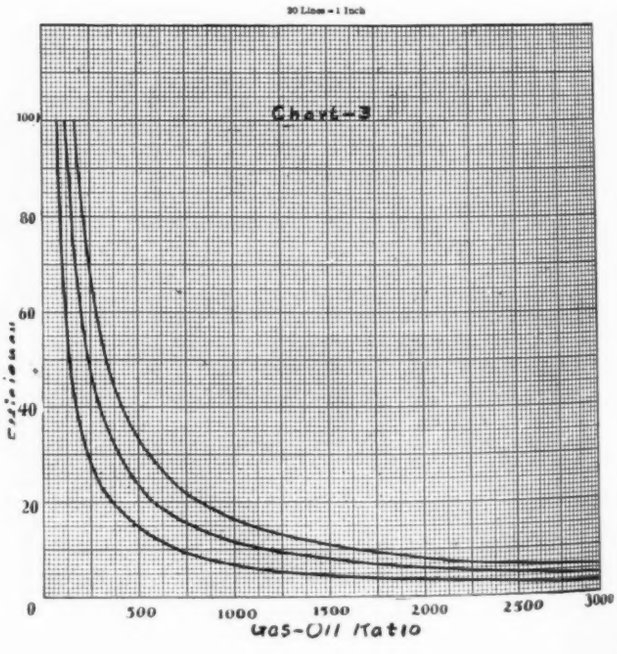
EXAMPLE 2

(1) The energy required to lift a barrel of oil (290 lb.) 4,000 feet is.....1,160,000 ft. lb.

(2) The energy of one cubic foot of gas expanded isothermally from a pressure of 1,360 to 15 lb. per square inch is.....9,730.8 ft. lb.

(3) The well efficiencies and gas volumes utilized are:

Efficiency Per Cent	Gas Volume Cu. Ft.
100	119
75	159
50	238
25	477
10	1,192
5	2,384
1	11,921



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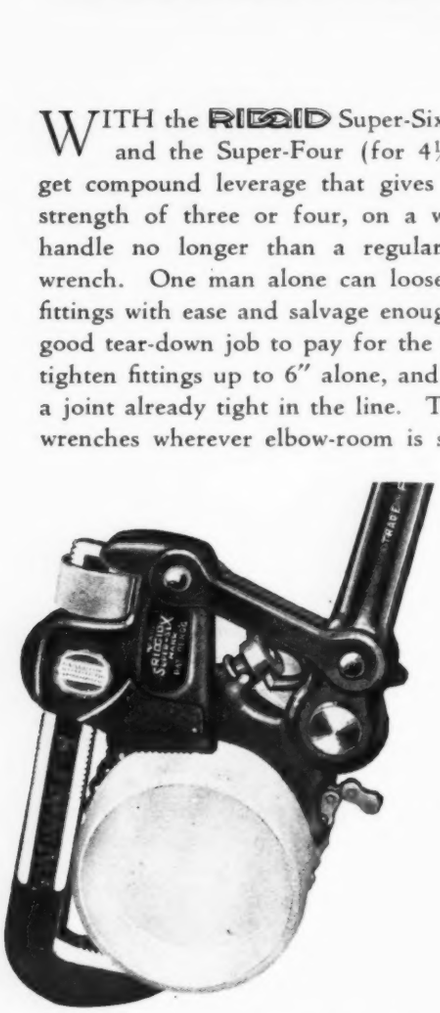

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EXAMPLE 3

(1) The energy required to lift a barrel of oil (290 lb.) 6,000 feet is.....1,740,000 ft. lb.

(2) The energy of one cubic foot of gas expanded isothermally from a pressure of 2,040 to 15 lb. per square inch is.....10,611.4 ft. lb.

(3) The well efficiencies and gas volumes utilized are:

Efficiency Per Cent	Gas Volume Cu. Ft.
100	164
75	219
50	328
25	656
10	1,640
5	3,279
1	16,397

The data under the above three examples are graphically represented in the three curves on Chart 3. These curves depict the efficiency and gas volume relation for the generalized well mechanism. The data indicate that (1) with an efficiency above 25 per cent the well has a decided oil well trend; (2) with an efficiency below 10 per cent the well has a decided gas well trend; (3) large gas volumes produce oil inefficiently; and (4) small gas volumes produce oil efficiently.

The data suggest the distribution of the actual wells in a pool which produce both oil and gas into at least two classes, oil wells and gas wells. An ideal gas well would be one in which the efficiency of the transference and transformation of the energy to the production of oil is zero per cent. An ideal oil well would be one in which the efficiency of the transference and transformation of the energy to the production of oil is 100 per cent. These two definitions would classify a well as an oil well when the efficiency is equal to or greater than a set minimum value.

The data show that in case a minimum value of 10 per cent efficiency were set the 2,000-foot well, to be produced as an oil well, could not have a gas-oil ratio in excess of 704, the 4,000-foot well in excess of 1,192, and the 6,000-foot well in excess of 1,640. In case the minimum value of 25 per cent efficiency were set the 2,000-foot well to be produced as an oil well could not have a gas-oil ratio in excess of 282, the 4,000-foot well in excess of 477, and the 6,000-foot well in excess of 656.

The minimum value of the efficiency set for an oil well in a pool should be sufficiently large to secure an adequately controlled supply of oil and to promote the advancement and proper application of mechanical devices in a program for increased efficiency and conservation in the production of oil and gas. A practical working value will probably be around 20 to 25 per cent. The oil wells and gas wells in a given pool would be produced simultaneously and continuously in accordance with prescribed regulations. The rate of production of the oil wells would be controlled by the adopted minimum efficiency value. The rate of production of the gas wells which produce some oil and are classed as gas wells, would be controlled by the present regulations governing gas wells or by new regulations to be made.

Conclusions

Conservation and efficiency in the economical production of oil demand measures that will force both the proper spacing of oil wells and the proper rate and methods of producing wells. Such measures if universally applied will be adequate to control scientifically and practically the development and the production of oil and gas from an oil pool.

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Banquet Given for H.V. McGivern

H. V. McGIVERN

ROUNDING out 30 years of service under one industrial banner, H. V. McGivern, of Oklahoma Pipe Line Co., a transporting subsidiary of the Standard Oil Co. of New Jersey, was recently presented with a fine watch, emblematic of his continuous service, at a banquet given in his honor at the Muskogee, Okla., Country Club. The banquet was occasioned by his retirement from active service and was attended by officials and veterans of the company which he served so long.

Born in the heart of the oil country it was only natural that he should fall in step with the progress of the petroleum industry. His early work was with an oil company in Pennsylvania and, during his march down the path of time, he has witnessed the growth of an infant industry to one which has become one of the dominant ones of the world. His first glimpse of an oil pump station was the Bear Creek station of the Union Pipe Line Co. It was at that time considered one of the largest in the world, delivering oil to a loading rack at Parker Falls through a two-inch line.

During these impressive years he witnessed a great economic struggle in the industry.

"Mr. Mac," as he is familiarly known, witnessed the construction of what was then one of the "Seven Wonders of the World." It was the building of a great oil carrier—a four-inch line from Hilliard Mills, Butler county, Pa., to Bear Creek station.

The natural gas industry, undeveloped at that time, has since become mammoth in size with long lines literally threading the nation. When the first gas line was built from Fair View, Butler county, to Parker's Landing, it resulted in much trouble, since regulators were unknown.

Like many veteran oil men who have witnessed the ever-changing picture of the petroleum industry, Mr. McGivern had his fling in politics. As a matter of fact he was more ambitious than the average Irishman who desires to bedeck himself with a policeman's uniform the moment he leaves Ellis Island, since he desired to be the boss of policemen and consequently served as mayor of Cygnet, Ohio, for 12 years.

In advancing through the ranks of the oil industry, Mr. McGivern spent more than a score of years in the eastern fields and he it was who opened the gate valve permitting the first gas to flow to Wheeling, W. Va., and to Toledo,

Heavy-Duty service saddle

The highest pressure saddle made for service and field connections—taps up to 2".

High-pressure work demands a concentrated bearing directly at the tap. This in the Skinner Heavy-Duty Service Saddle is supplied by the tremendous pull on a raised pressure platform, of three large bolts. The lead gasket, riveted in place, cannot shift during installation.

Made of malleable iron, it has many times the strength demanded by the highest pressures.

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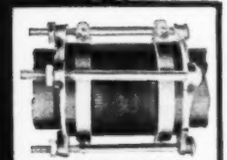
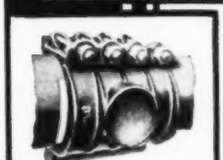
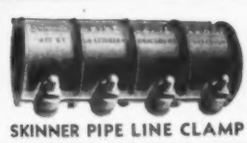

SKINNER COLLAR LEAK CLAMP


SKINNER H. P. SADDLE CLAMP

SKINNER BAND CLAMP

SKINNER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Crooked holes mean increased drilling costs . . . greater production costs!

SYFO Clinograph provides the remedy . . . offering an easy, infallible means of determining the degree of deviation without burdensome interruption to drilling. Leased—not sold . . . it **operates without acids;** is accurate and provides a permanent record on paper for filing.

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Room 1, Central Block

The SYFO Clinograph

Ohio. During his life of service he was identified with the National Transit lines, Natural Gas Co. of Wheeling, Toledo Natural Gas Co., Ohio Oil Co., Buckeye Pipe Line Co., and with the Oklahoma Pipe Line Co.

E. H. Leroux, president of the Oklahoma Pipe Line Co., presided at the banquet, which was attended by Richardson Pratt, vice-president of the Carter Oil Co., and the following members of the executive personnel of the Oklahoma Pipe Line Co.: Paul Griffin, Chas Nelson, Jr., H. P. Hellinghausen, R. W. Sparrowhawk, Bruce Ramsey, T. M. Moroney, C. E. Foster, A. E. Erickson, T. D. Walkley, C. B. Randels, C. C. Duckworth, W. S. Foster, Reece Henry, I. N. Willis, Leo J. McGivern and James M. Bradley.

California Gasoline Line Under Construction

THE accompanying pipe line view is of the new six-inch gasoline line now under construction by the Associated Oil Company of California. The line will run from the north Belridge field, via Kettleman Hills, to Coalinga, and on to Monterey Harbor.

Part of the line is not new, but is being taken up and reconditioned by burning off the collars, scraping and painting. The condition of this old line is comparatively good, regardless of the fact that it has been under ground and in use for over 28 years. This portion of the line which constitutes about 90 miles of the 160 to be constructed, was formerly used for the transportation of crude oil. The new line will carry casinghead gasoline.

This important part of the 1931 expansion and construction program of the Associated company, is expected to be rushed through to completion within 90 days. The picture of the work shown herewith was taken near the town of Soledad, some fifteen or twenty miles from Monterey.

The line is to be all acetylene welded.

Two New Leschen Distributors

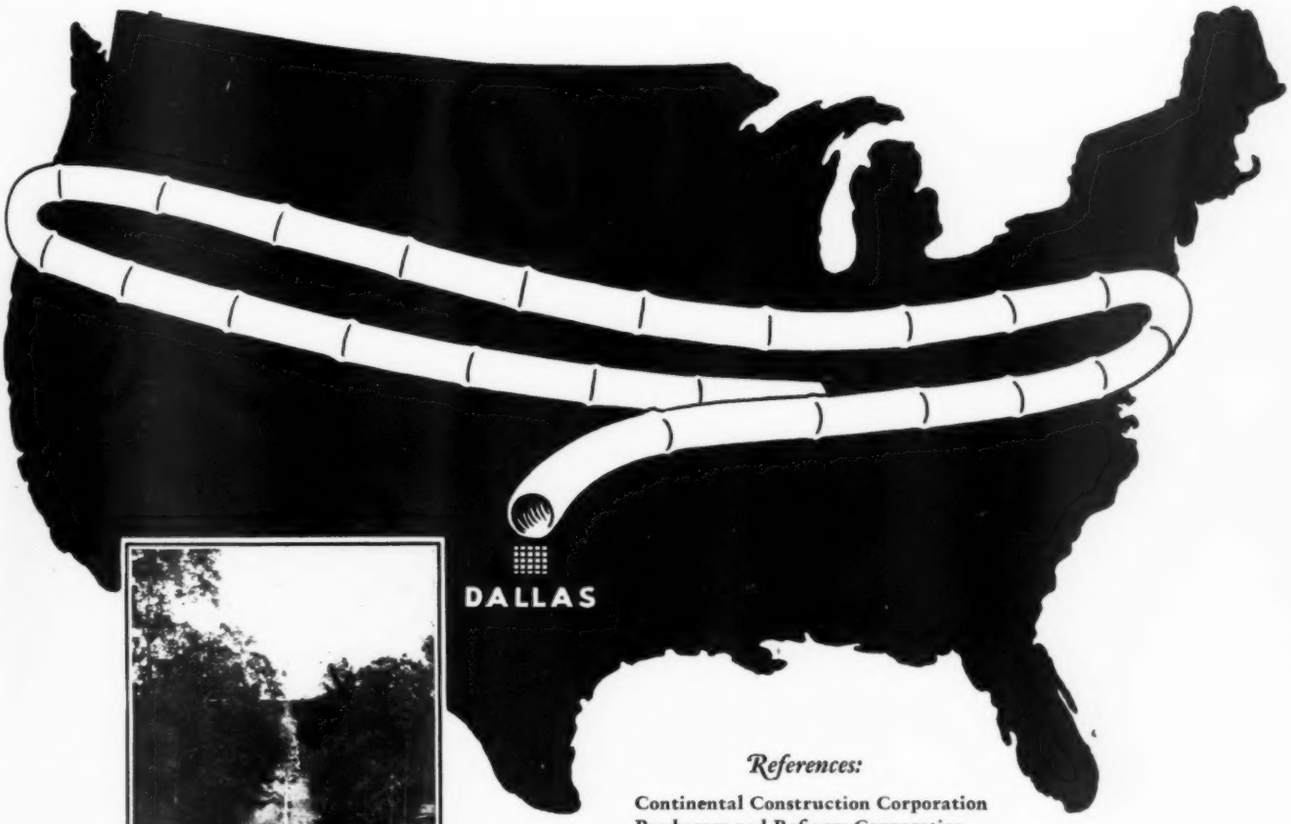
ANNOUNCEMENT has recently been made that Leschen wire lines for all oil country purposes are now being distributed in the Mid-Continent field by the Hinderliter Tool Company and the Norvell-Wilder Supply Company, the former with headquarters in Tulsa, Okla., and the latter with headquarters in Beaumont, Tex.

This is, indeed, a strong combination as Leschen wire lines have an enviable reputation in all of the important oil fields of the world.

It is pointed out that Leschen wire rope and the oil industry had their beginning at about the same time, and the Leschen Company is credited with having produced one of the first successful wire drilling lines.

PIPE LINES LAID BY OKLAHOMA

would reach more than twice across the continent . .



References:

Continental Construction Corporation
Producers and Refiners Corporation
Southern Natural Gas Corporation
Oklahoma Natural Gas Corporation
Missouri-Kansas Pipe Line Company
Panhandle Eastern Pipe Line Company
Panhandle Illinois Pipe Line Company
Mississippi River Fuel Company
Ajax Pipe Line Company
Cities Service Company
Shell Pipe Line Company
Lone Star Gas Company
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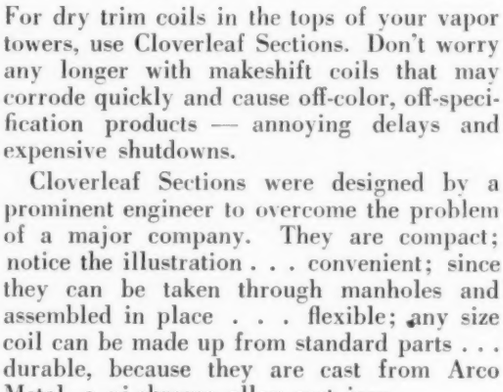
Banish tower coil failures with STERLING CLOVER-LEAF SECTIONS

For dry trim coils in the tops of your vapor towers, use Cloverleaf Sections. Don't worry any longer with makeshift coils that may corrode quickly and cause off-color, off-specification products — annoying delays and expensive shutdowns.

Cloverleaf Sections were designed by a prominent engineer to overcome the problem of a major company. They are compact; notice the illustration . . . convenient; since they can be taken through manholes and assembled in place . . . flexible; any size coil can be made up from standard parts . . . durable, because they are cast from Arco Metal, a ni-chrome alloy cast iron.

For reflux coils, reboiler coils or similar types of exchanger work they have no superior.

Let us tell you of their increasing use. A word to the nearest office will bring you full information without obligation.



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RECENT *in* Gasoline

By RICHARD H.
Camden Refinery, Houston

Richard H. Cook

SOME distillates, when treated with Doctor solution, do not contain enough free sulphur to further the reaction to completion, or produce what is termed a good "break-out." These distillates must have sulphur added in one of several ways. In some methods this sulphur is added by hand, as flowers of sulphur or sublimed sulphur used in batch treatment with an agitator, others with continuous treating plants pass a portion of the distillate through drums containing stick sulphur and control the amount needed by the volume of the stream passing through the drums. This sulphur saturated stream enters the treaters just preceding the chemical mixing coils. Still another method is to make use of some distillate which is corrosive because of too much free sulphur. By blending these two together treating may be carried on rendering the high sulphur distillate non-corrosive as well as making the low sulphur distillate sweet to the Doctor test. This method finds a place in the small refinery operating on various crudes or doing both cracking and skimming operations. Often rerun gasoline is sour to the Doctor solution and necessitates the use of free sulphur with the treatment, while most straight-run distillates contain sulphur in sufficient quantities to produce a "break-out" when blended with the rerun gasoline before treatment. Another method to correct this form of corrosion caused by the addition of too much sulphur is to undertreat gasoline to the point where it is just "breaking-out," but will filter off slightly reactive to Doctor solution, and mix this gasoline with the high sulphur gasoline and thereby rendering the blend negative to both Doctor and corrosion tests. All the above-mentioned must first be given a trial treatment in the laboratory to determine amounts of each to blend as they vary with the nature of each condition.

Gasoline or distillates containing only hydrogen sulfide are usually washed with some good neutralizing medium such as a caustic wash, using about 10 per cent caustic solution. With this treatment about the only type of operation liable to meet with difficulties is the continuous treating. For some reason or another the caustic contacting may be held up for only a short period, but long enough to let sufficient hydrogen sulfide pass out into the tank unnoticed, and even when a Doctor test is made on the tank, unless extreme care is taken, it might be reported as negative. However when a corrosion test is run it will be slightly off. This form can be detected if a much larger sample of the gasoline be shaken with the Doctor solution and extreme care in watching for the brown film which will pass away almost as soon as it appears. Retreatment with a small amount of caustic will remedy this condition.

Frequently crude oils contain upwards of 1.0 per cent sulphur and when this is the case so many times corrosive

PROGRESS

Treating

COOK, *Chief Chemist, Oil Company of Texas*

gasoline is the result. This is usually expected, however, and arrangements are made in the treating to take care of the excess sulphur. In most cases the mercaptans which react with Doctor solution and the free sulphur are so proportioned that the "break-out" is produced without further addition of any reagent.

Upon the preliminary analysis of a crude the chemist will report the sulphur content, also the method to employ for treatment of the overhead. It is often a crude containing below 1.0 per cent sulphur will finish a gasoline which only necessitates a caustic wash for removal of hydrogen sulfide to be reported as an easily treated gasoline. With the small experimental still the time from fire-to-finished gasoline is only a matter of two or three hours. In this time the reactions which prove so disastrous to p'ant operation on a large scale may be overlooked. Then when the plant starts operation on this crude, the streams are tested and prove non-corrosive after a caustic wash, but it is found that after setting for several hours in the rundown tank that even after a strong caustic wash the gasoline is very corrosive. Much time and a tank or two of gasoline are spoiled in this discovery. This condition can be avoided by the pumping of small amounts of caustic from 5 to 10 degrees into the vapor line of the unit.

All crudes can be assumed as containing from mere traces to quite an amount of acids, either organic or mineral; most all these acids will react with hydrogen sulfide to form sulphur dioxide, which is a volatile and water soluble gas. The gas will pass through the fractionating tower along with the hydrogen sulfide and the lighter fraction vapors of the crude. Upon setting, in rundown tanks, these two cases began to react thus: $SO_2 + 2H_2S = 3S + 2H_2O$, giving us free sulphur which will float on the water line in the tank and slowly dissolve back into the gasoline, rendering it off-corrosion. There is also a reaction with the oxygen in the air and the hydrogen sulfide, thus: $2H_2S + O_2 = 2H_2O + 2S$ which will deposit free sulphur in the tanks, and later impregnate the gasoline to such an extent as to render it corrosive. Hydrogen sulfide will also corrode the condenser coils in the unit, the tanks and rundown lines, so we may assume that the placing of caustic in the vapor lines serves a triple purpose, that of removing the acid gases such as sulphur dioxide, the removal of the corrosive gases such as hydrogen sulfide, and the removal of the sulphur depositing gas with caustic before it has had time to react with the sulphur dioxide or the oxygen in the air.

All cracking plants produce an abundance of light sulphur gases, which it becomes necessary to remove before the distillate is rerun. It is not at all uncommon for a refiner to simply treat the pressure distillate first with acid, and water wash, and then with Doctor solution or some other metallic salt to remove mercaptans and other souring compounds. This practice in most cases is erroneous and with the treatment of acid first on the distillate much free sulphur is formed by the reaction of sulphuric acid on the hydrogen sulfide thus: $H_2S + H_2SO_4 = S + SO_2 + 2H_2O$. This condition can be avoided by the use of a caustic wash on the pressure distillate before it goes to rundown tanks.

An **"AMERICAN"** *with Gas Engine*

Pictured is an "American" No. 4-A Fig. 1822 oil well pumping unit connected to a gasoline engine.

"American" units have been particularly designed to meet the various drive requirements of different localities.

"American" units are adaptable for pulley, V-belt or direct drive by gasoline engine or electric motor.

Detailed figures and engineering data of typical installations of this equipment in both this country and others are available. Ask for them!

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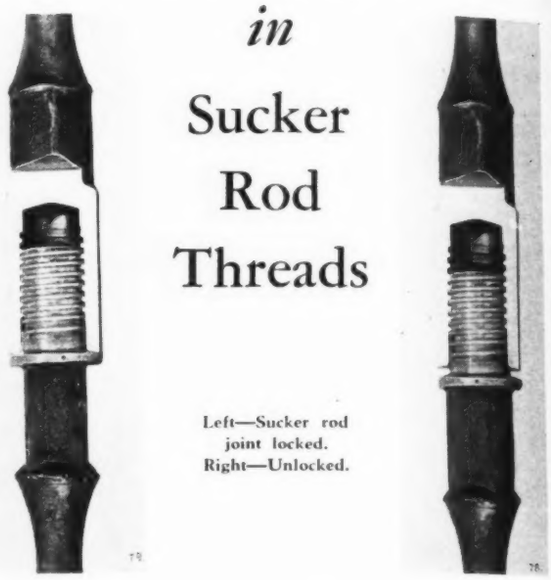
New Developments *in* Sucker Rod Threads



Left—Sucker rod joint locked.
Right—Unlocked.

PUMPING cost statistics gathered by the production departments of various oil companies have served to emphasize the economic importance of organized effort to decrease sucker rod failures.

The solution of problems involving the fatigue strength of materials naturally depends on continued metallurgical research and experiment. A large percentage of sucker rod trouble is, however, directly traceable to unscrewing of the joints. The failures in this classification caused by improperly made up joints, whether due to dirt or battered shoulders, can be eliminated by education of the rod crews. There has been, however, no satisfactory means of preventing properly made up joints from working loose under the vibration of pumping. Various locking devices have been suggested from time to time, but in all instances there were basic objections which made them impractical.

Every field engineer is familiar with the costly troubles which result when a joint becomes unscrewed through vibration,—such as pin breaks, body breaks which occur as a result of dropping, fishing, and the loss of production during the down time. It is believed that such failures with their attendant losses will be eliminated by sucker rods with the Dardelet self-locking screw thread, which are being manufactured and sold by the S. M. Jones Company.

These rods are not only designed to provide self-locking joints which will remain tight under all operating conditions, but they are insured against breakage in the threaded portion while in pumping service.

The insurance plan takes into consideration the fact that a joint break means a loss much greater than the mere cost of the broken rod. The insurance certificates which are delivered with each shipment of Dardelet rods guarantee the payment of $30 for each joint broken while in service. This sum represents the cost of the broken rods plus the average expense of recovering the broken string from the well.

The Dardelet thread applied to bolts and nuts and screws is already known to oil men through exhibits and demonstrations at the Petroleum Expositions at Tulsa and Los Angeles. The Dardelet threaded sucker rod has been developed through extensive engineering research conducted through the co-operation of the Gulf Research Laboratories, the S. M. Jones Company and the Dardelet Threadlock Corporation of New York, owners of the American patents.

Construction of

OIL *and* GAS PIPE LINES

CITY GAS SYSTEMS

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FOR nearly a half century, Dearborn products have combined the analytical and experimental work of the chemist with the practical, mechanical requirements of the engineering problems involved.

Scale Removal

Dearborn Special Formula No. 134 dissolves scale quickly and thoroughly, regardless of hardness or thickness of the deposit. Used extensively on water lines, pumps and all scaled equipment.

Cooling Water Treatment

By means of laboratory analysis and frequent tests, satisfactory results are produced in this very specialized phase of water treatment. Use it for prevention of scale in Diesel engines, compressors and condensers.

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In low pressure boilers, water troubles were sometimes regarded indifferently, but in the new equipment, both economy and safety are dependent upon their proper control. Dearborn service follows exact scientific lines, starting with laboratory analysis of the water and following through to satisfactory and economical elimination of scale formation, foaming, pitting and corrosion, with full responsibility for producing the results desired.

Dearborn Cleaners

Dearborn Cleaner No. 7 opens drains, cleans caked and extra dirty concrete floors; No. 5 used for general service in oil and grease removal; No. 3 for washing greasy clothing. There is an efficient Dearborn Cleaner for every service.

The Master Coat

The NO-OX-ID Master Coat is protecting many hundreds of miles of pipe line effectively and economically. As recommended for long time protection this coat consists of three parts: (1) NO-OX-ID applied on the metal. (2) NO-OX-ID-IZED Wrapper, wrapped spirally over the NO-OX-ID and (3) NO-OX-ID Service Coat over all. Let us send you interesting facts.

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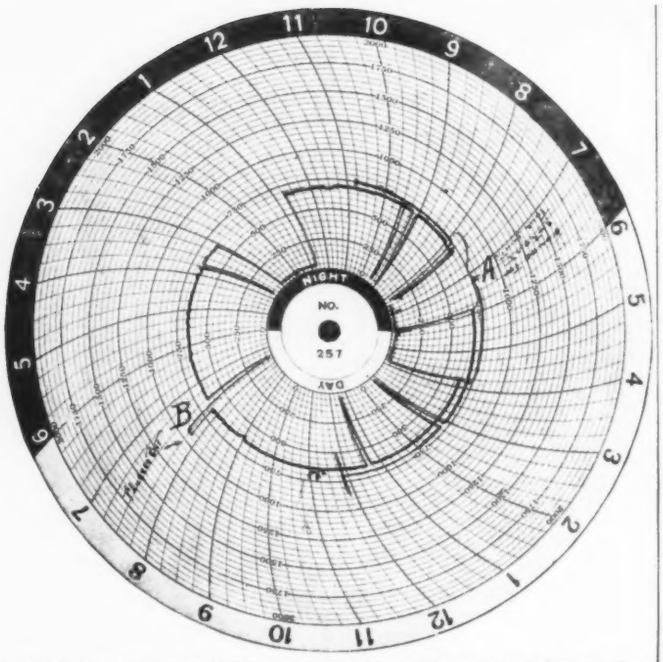

Typical Chart: Covers 36 hours of operation. The pressure drop at the lower end of bracket A enabled the driller to discover two cut out joints. Resuming operations the pressure came back to 750 lbs. At B is shown the pressure rise required to get circulation after lowering the bit into the cuttings.

Mud Pump Pressures tell a Story!

Savings:

in twist-offs, finishing jobs, equipment, gauges — For example: 27 cut-out joints indicated on one well, and not a twistoff. Saves mud pumps, hose, valves, fittings from excessive pressures. Gauges last indefinitely.

Safety:

Accurate knowledge of true pressures enables the driller to protect his crew from the dangers of blown out mud ends and hose.

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Progress is based upon knowledge. Research and data on circulation problems are made possible from pressure data. Charts of pump pressures gives this data in record form.

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Non-Clog *Non-Pulsating*

Mud Pump Gauge and Recorder

shows and records the true pump pressure accurately and readably. Instantly sensitive to changes, yet the guage hand is steady and the pen record readable.

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LONG BEACH CALIFORNIA

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Houston, Texas

The laboratory work has been supplemented by successful field service tests covering a period of seven months.

The Dardelet thread locks by reason of the wedging action of tapered thread faces which come in contact when the box is tightened against the pin shoulder. These tapered thread faces are found at the bottom of the pin thread groove and at the crest of the box thread. (See cross-section views.)

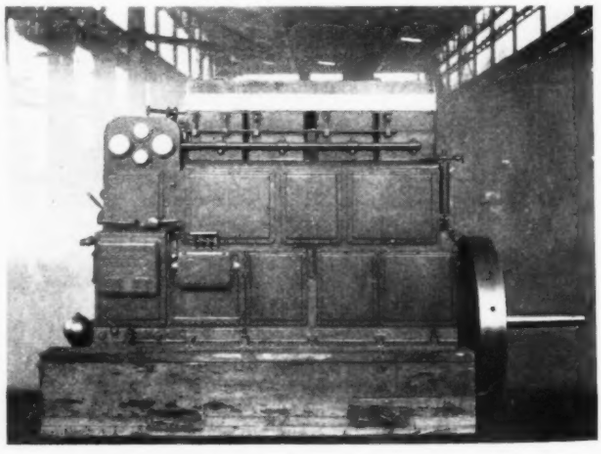
When the box and pin are being screwed together, the threads are in the unlocked position and turn freely until the box is seated against the pin shoulder. When the box is seated against the pin shoulder a partial turn of the wrench causes the box and pin to rotate without advancing. The box thread moves directly across the pin thread groove until the flanks of the threads meet and the tapered thread faces are powerfully wedged together. The joint will now remain securely locked under all service conditions for the same reason that a taper pin remains tight in a tapered hole. Box and pin have become in effect one mass. There can be no rocking movement to set up fatigue stresses.

When it is necessary to unscrew the joint, the threads are readily unlocked by turning the box section backward with the wrench. This re'eases the pressure generated between the tapered locking surfaces and the joint easily spins apart. The threads are uninjured by the locking action, consequently Dardelet threaded rods may be used over and over again and will always re-lock.

Dardelet threaded pins are materially stronger and have greater resistance to fatigue stresses than standard threaded pins. There are three reasons for this increased strength and fatigue resistance—the Dardelet thread is less deeply cut than the standard thread, leaving a greater root area,—it is free from so-called "notch effect", and to this strength of material and form is added the strong frictional lock,—a combination which makes for maximum resistance to destructive service forces.

New Pumping Station To Boost Oil Delivery

A DIESEL engine-powered pumping station is being erected by the Illinois Pipe Line Company near Brookville, Indiana, to increase the capacity of an existing line.



One of two enclosed Type-FP-4 Diesels ready for shipment to oil-pumping station near Brookville, Ind.

The 8-inch oil line, which runs 120 miles from the pumping station at Elwood, Indiana, to the Standard Oil Company of Ohio's refinery at Latonia, Kentucky, makes a present delivery of 8,000 barrels per day.

A pair of 4-cylinder 130-horsepower Diesel engines, recently shipped from the Cooper-Bessemer plant at Grove City, Pa., will direct-drive triplex vertical pumps through reduction gears. The new location is in southeastern Indiana, near the Ohio border.

When writing MARTIN DECKER CORP., *please mention The Petroleum Engineer*

Measuring Piston Ring Temperature

The use of fusible plugs in obtaining close approximate temperatures of Diesel engine piston rings in connection with a study of lubrication problems, is followed with gratifying results in several Mid-Continent pipe line stations. The method was suggested and perfected by the research department of the Standard Oil Co. of Indiana and J. B. Harshman, master mechanic, Stanolind Pipe Line Co.

It was developed to do away with the time-consuming practice of testing one lubricating oil after another over long runs under fairly uniform conditions and comparing the results. The plugs are inserted in the back side of the ring. When the engine is in operation some of these will melt, while others with a higher fusing point will remain. The temperature of the ring is between the melting point of the highest fused plug and the lowest melting point of the remaining plugs. Heat conductivity of cast iron is rapid and temperature of the oil on the outer face of the ring is assumed to be very close to that of the fused plugs. With this method the temperature drop from the top to bottom rings may be obtained.

The plugs are made with alloys. Varying percentages of lead, tin and bismuth are used to make the plugs with varying melting points. This information in detail may be obtained from E. H. Hillman, of the Standard Co.'s technical department, 910 South Michigan Ave., Chicago.

The fusible plugs are inserted in 1/32-inch holes drilled ⅛ of an inch in depth in the back of the rings. To overcome any trouble resulting from the plugs falling out due to vibration some of the holes have been threaded with a tap which has been broken off to allow threading at the bottom of the hole. In other instances this has been overcome by wedging the alloy in the hole with a center punch on the side of the hole. By using the latter method the punch causes a slight projection of the cast iron to make the plug fast in its place. Before insertion in the holes drilled in the rings the plugs are cut in chunks of suitable shape. The plugs with a high lead percentage are comparatively easy to pound into position. This is done with a ball hammer which has been found to be the most satisfactory for pounding all plugs. After they have been pounded in the excess metal is scraped off to a smooth finish flush with the ring surface. Extreme care is necessary.

The plugs are of such small size that no trouble has been experienced with their fusing and running into the space back of the piston ring. In the instances where the plugs have melted, it has been noted in several cases the alloy remained in the hole rather than running out into the ring groove. This is attributed to cohesiveness of the alloy.

Whenever this gives trouble in checking temperatures, this type of fusion may be detected by making a small center punch mark in the center of the plug. When this plug fuses the mark, of course, will be covered over by the melting alloy indicating the melting point has been reached.

While this method of study of lubrication problems entails the pulling of pistons, it is by far more rapid than the method of observing several oils over long periods. It also gives a close approximation of the oil film temperature in the cylinder, the main factor in lubricating oil deterioration.

Raschig Rings

Made Especially for Refinery Service

Genceraco Raschig Rings are especially made for refinery service, made a little better than at first seems necessary. . . These are rings made to resist the softening action of oils and vapors. They are individually molded, hard-pressed for maximum density and structural strength, and hard burned and vitrified so they are fully non-absorbent. Genceraco Raschig Rings are practically indestructible.

We can furnish these packing rings in any of the standard shapes and sizes. May we send a few samples for a test?

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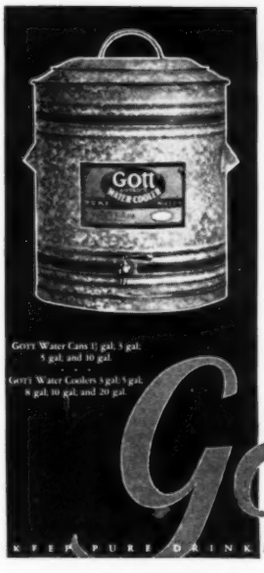
71 West 31st Street NEW YORK, N. Y.



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Gott Water Coolers 3 gal, 5 gal, 8 gal, 10 gal, and 20 gal.

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When you have a Gott Water Cooler handy, you will always be assured of a fresh supply of pure drinking water kept delightfully cool. *Order one from your supply store . . . now!*

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Winch-Equipped Tractor Pulls Deep Wells

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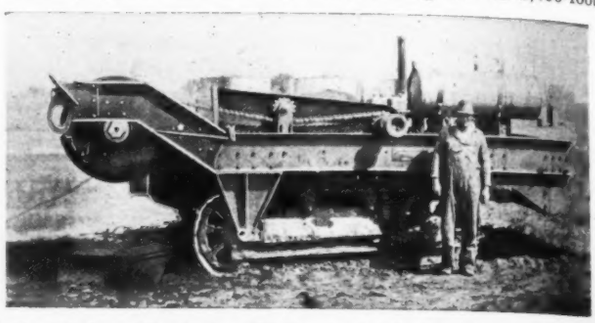

Indian Territory Illuminating Oil Company's Big Winch-Equipped Tractor.

The tractor is commonly used for pulling 2½-inch tubing set at 6,000 or more feet, although it is sometimes used for general duty.

Fuel and Gas Engineering Institute Completes Field Work

Tests of broad interest in several phases of fuel utilization marked the six months' field work of the course in Fuel and Gas Engineering at the Massachusetts Institute of Technology now brought to a close. At the Tide Water Oil Company's refinery in Bayonne, New Jersey, gas and oil-fired crude stills, solution stills and cracking coils were studied.

The efficiencies of a gas producer and a billet reheating furnace were determined at the Lackawanna plant of the Bethlehem Steel Co. and extensive tests were made on the dry quencher and Koppers liquid purification system at the gas plant of the Rochester Gas and Electric Corporation. The 1,400-pound boilers and turbines at the Edgar station of the Edison Electric Illuminating Company of Boston were also subjects for part of the test work.

The field work follows a year's study in theory of combustion, natural and manufactured fuels, power development, furnace design, utility economics, fluid flow, heat flow and kindred subjects in the graduate course at Massachusetts Institute of Technology.

Correction

THE following acknowledgment should have accompanied the paper "Bottom-hole Pressure in Oil Wells," by C. V. Millikan and C. V. Sidwell, which appeared in the May issue of The Petroleum Engineer:

"Presented before the Petroleum Division, American Institute of Mining and Metallurgical Engineers, Tulsa, Oklahoma, October 3, 1930; being published in Transactions A.I.M.E., Petroleum Development and Technology, 1931."

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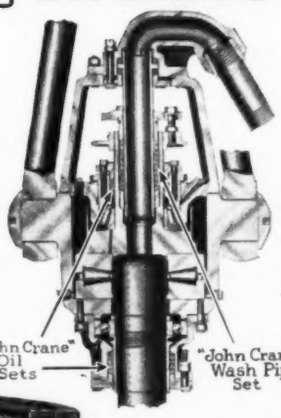

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TRANSPORTING *in* South

By WILEY

THE ordering, transporting and stocking of oil well material for use in Venezuela is quite different from methods employed in the United States fields, due to the fact that there are no factories or supply stores within calling distance.

All material requirements must therefore be anticipated from six months to a year in advance. On account of this condition, most of the large oil companies have established central or large receiving warehouses on Lake Maracaibo, it being large enough to permit freight steamers to harbor. This large receiving warehouse must supply all the different field warehouses located along the lake and in the interior. The central warehouse is complete in every detail, maintaining different departments for every class of supplies. Besides carrying a complete stock of oil well supplies, a well stocked lumber yard, a furniture department, a stock of boat parts, railway supplies, road-building materials, electrical equipment and every kind of material necessary to build and maintain a complete camp may be found at the warehouses.

To enable the material department to keep the warehouses stocked, the material man in each field warehouse is given a program of drilling and construction work to be done in that field during the next year. He then requisitions what is needed, ordering many extras to take care of emergencies. An extra large number of spare parts for all engines and mechanical devices must be carried, as a great loss of time and money would result should it become necessary to order extra parts from the United States should some of the machinery break down.

An interior port and small boats with field supplies.

After the material man has made up the requirements, this list is sent to the main office to be checked with material on hand and held at other warehouses. In many instances material on hand at other warehouses not in use may be transferred to fields having greater activity. This list is checked very carefully and is then sent to the United States for purchase.

The material man in the field must then prepare to care for the material when it arrives; warehouses must be built, pipe and lumber racks constructed and at the same time care

Oil Field Materials America

MARTIN [1]

must be taken of all immediate needs in the field. The warehouses in the fields represent the latest developments in warehouse construction. Large sheet iron structures with cement floors are built, having the latest type of steel bins and shelving, each class of material being placed in certain sections, each piece being marked by number or catalogue name. In stocking large quantities of small fittings and small material of the same size and shape, metal trays are used and equal amounts are stocked on each tray and then a certain amount of trays put in one section having a card on the end of the trays stating the name and exact number of pieces in each section, thus making it comparatively easy for the material man to check his stock and take inventory. A complete visible card index system is kept on each piece of material, these cards being checked daily by a man who does nothing else but check the cards against his stock. All materials going out or coming in are checked and recorded by this card system. All materials outside the warehouse are handled by a certain man, this material consisting of pipe, lumber, cement and other material too large to be kept in the main warehouse. This stock is kept in the same perfect order as is the material inside, the pipe and lumber being stacked according to size and kind and placed on concrete foundations. The cement is kept in a separate house. All movement of this material is recorded by the same card system that is used for the warehouse.

The greatest problem in the handling of material is transportation, most of it having to be moved by water. This necessitates the transferring of the material from boat to boat and wharf to wharf and for this reason the material is strongly boxed and packed. The freight steamer from the United States or Europe must unload the material on large barges. It is then unloaded and checked on the company wharf, then reshipped to the different fields, a large amount of it being placed in stock at the main warehouse. The materials to be shipped to the field warehouses are then loaded on a smaller oil or gasoline burning boat and delivered to the wharf at the various camps.

One of the most difficult camps to reach is situated some three or four hundred miles from the main warehouse. The material for this camp must be loaded on a large lake boat which travels to the mouth of a small river. The material is then transferred to small barges. These barges are then pulled by a 30-foot gasoline launch up a river that is very shallow and full of sandbars. It is necessary to wait until the rainy season when the river is high to haul heavy or large loads of supplies such as pipe and machinery. The unloading facilities at this warehouse port at one time consisted of only a hand winch. While using this winch to unload a large pipe-threading machine, the cable broke, letting it fall into the water where it remained for six months until a power hoist could be obtained.

From these barges the material is then hoisted and placed on small rail cars which are pulled by a gasoline engine. It is transported to the field warehouse, unloaded, checked and put in stock.

[1] Mr. Martin has just returned from several years in South American oil fields.

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Pipe Line Station Design *and* Control

By JOHN M. McGREGOR[1] and T. D. WILLIAMSON[2]

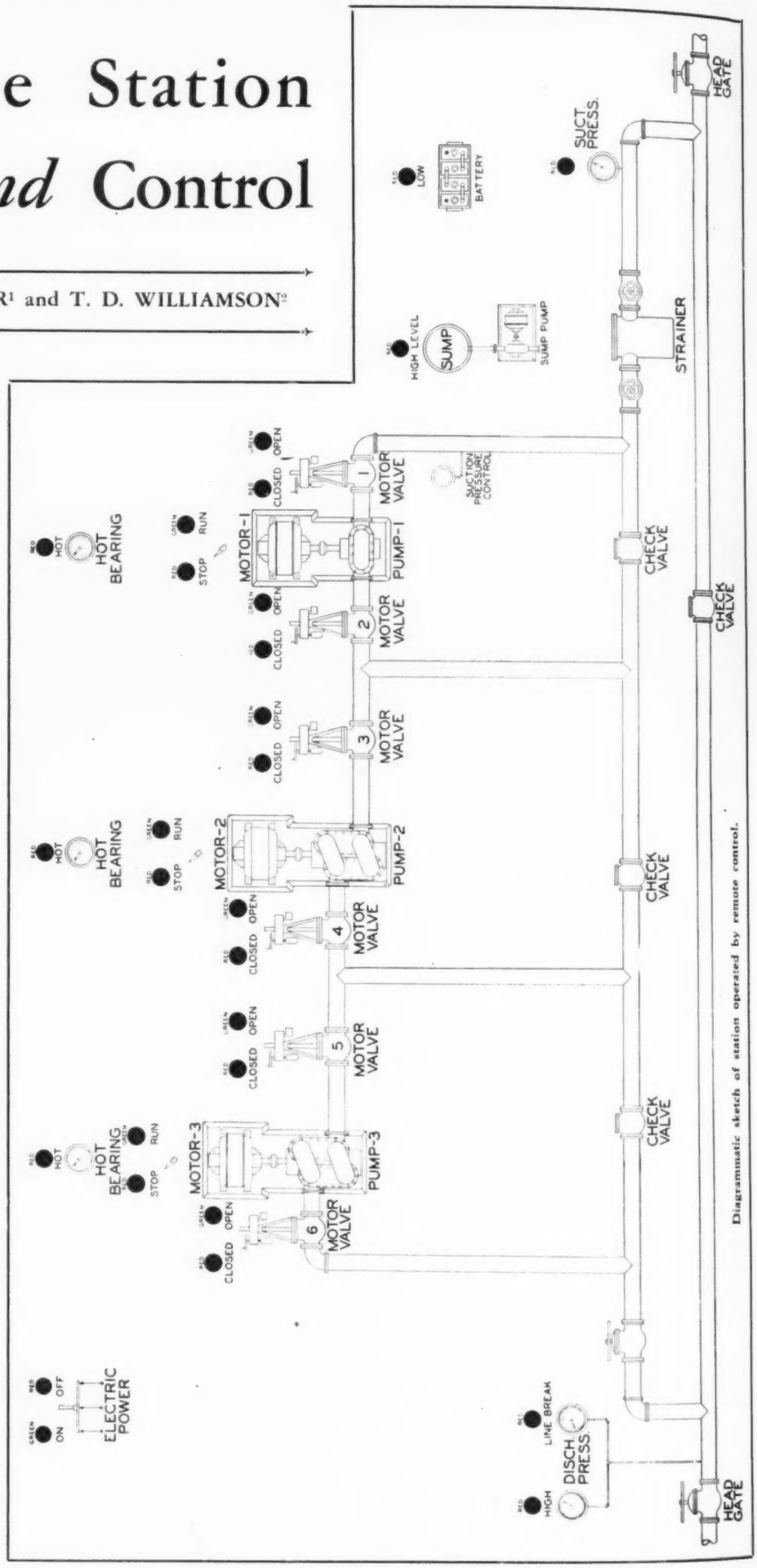
CONSIDERABLE interest has been shown in an article entitled "Some Suggestions for Centrifugal Pump Operation" which appeared in the March issue of "The Petroleum Engineer." As a result the author of that article has been asked to write a more detailed explanation in conjunction with Mr. T. D. Williamson, and describe the use of automatic control on such a line.

The example taken was a 12-inch line 258.3 miles long, delivering crude oil of 80 S. S. U. and 38 degrees A. P. I., line pressure not to exceed 700 pounds per square inch. The distances between stations were such that this pressure would not be exceeded when delivering the maximum quantity of 2,200 barrels an hour.

It was contended that if a correct study of the hydraulic gradients be made, if the head-capacities of the pumps be known and the line be a "closed" system, control could be automatic and no throttling of the pumps would be necessary. It will be recalled that instead of the accepted practice of having two multi-stage pumps, delivering equal pressures, these pumps would have impellers of different diameters to give a variation of pressures and, in addition, a single-stage pump is used, this pump to be designed to withstand whatever residual pressures might be encountered.

By the arrangement of three pumps in each station and with seven stations on the line a large combination of pumps can be used with a resulting large variety of pressures.

Several people who have discussed the proposed lay-out are skeptical of the practicability of



[1] Engineer, Chapman Valve Co.
[2] Petroleum Electric Co.

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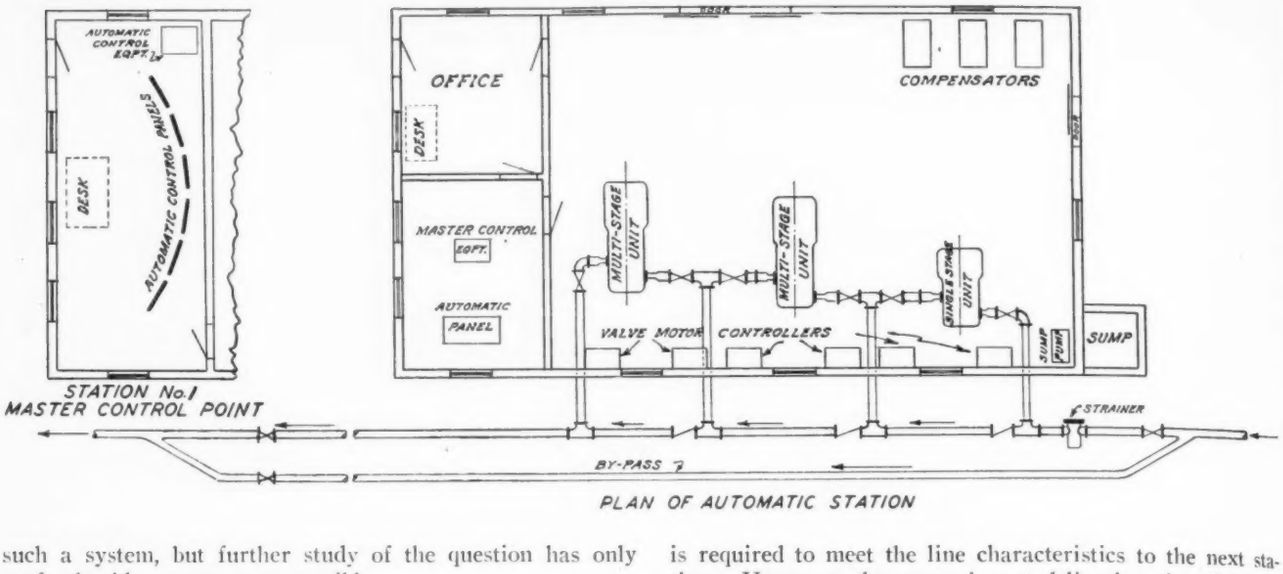


PLAN OF AUTOMATIC STATION

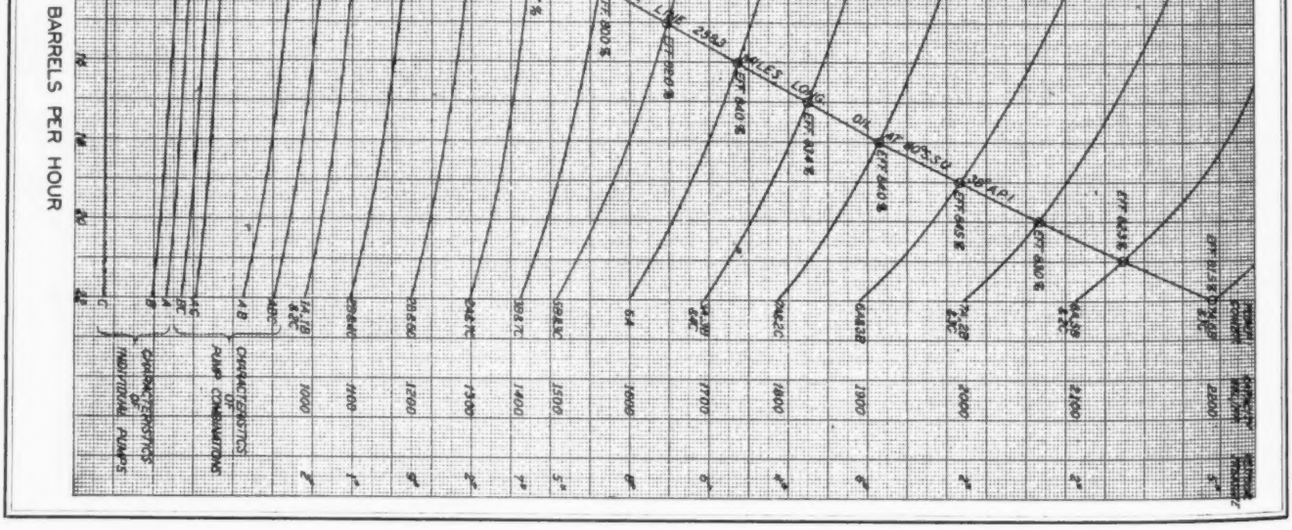
such a system, but further study of the question has only made the idea seem more possible.

There is no doubt about the operation of a "closed" system, for this has been done successfully before. Working tanks are not necessary where centrifugal pumps are used, although it might be desirable to have a tank at each station to receive the oil in the event of a line break.

The line characteristics and the head-capacity curves of the various pump selections have been plotted and are shown on accompanying chart. At the points of intersection the pump efficiencies are noted and on the right are shown the pump combinations, the various capacities and the residual pressures at receiving end.

The point has been raised that a pump capable of delivering 2,200 barrels an hour with discharge gate fully open will deliver that amount and not only 1,000 barrels, as shown for first condition where pump "A" is operated, giving a total pressure of 385 pounds when only 137 pounds is required to meet the line characteristics to the next station. However, the pump is not delivering the oil to the next station only and the system must be considered in its entirety. It cannot be gainsaid that if the line could withstand the total pressure of approximately 3,600 pounds when delivering 2,200 barrels an hour and the forty-nine stages of the twenty-one pumps available could be placed at the initial point, the system could be operated successfully, for it would be a simple matter to meet a decreased demand for oil by cutting out the correct number of stages. However, as it is not possible to build a line to withstand the pressures involved, nor would it be practicable to have all the pumps together, they are placed at such intervals along the line that will enable the pressures to be kept below 700 pounds.

The "Hydraulic Gradients" for capacities ranging from 1,000 barrels an hour to 2,200 barrels an hour are shown and the residual and additive pressures are plotted for two conditions to illustrate how such a curve coincides with the


TOTAL LINE PRESSURE IN POUNDS PER SQUARE INCH
HUNDRED BARRELS PER HOUR
CHARACTERISTICS OF INDIVIDUAL PUMPS
CHARACTERISTICS OF PUMP COMBINATIONS

line characteristic-head capacity curves shown on the other chart. The two conditions plotted are for the two extremes mentioned above. The residual pressures at all capacities being near "Zero," all gradient lines converge at receiving end as shown. The pump selection for the higher capacity as it appeared in the previous article consisted of pumps "A" and "B" at each station except at the last, where the pump "B" was not operated, "C" taking its place. Referring to the chart, it will be seen that at the first station the total pressure of the two pumps is 536 pounds and the line pressure is 528 pounds, leaving a residual of only 8 pounds. The same combination of pumps is used at each of the next five stations, gradually building up the total pressure and the residual pressure until at station number 7 the residual pressure is 149 pounds, making the use of combination of "A" and "B" too high. Consequently, pump "C" is used in place of "B," making a pump pressure of 385 pounds, added to which is the residual pressure of 149 pounds, making a total of 534 pounds. The line pressure required to deliver the oil to terminal point is 529 pounds, leaving a residual pressure of 5 pounds.

Further examination of the "Hydraulic Gradients" shows that to deliver 1,000 barrels an hour the use of one "A," one "B" and two "C" in combination will meet the hydraulic gradient at number 4 station, permitting the remaining stations to be by-passed.

In common with every other industry, the pipe line companies are improving methods of operation and attempting to lower installation costs. The last two years have seen considerable progress in these directions, due largely to the co-operation of pipe line superintendents and engineers with the engineer representatives of equipment manufacturers.

As previously mentioned, the use of fully automatic pipe line pumping stations, controlled from a distant point, has been proved a commercial success. The control system which is described below is therefore an adaptation of the proven methods to the operating conditions of this particular pipe line.

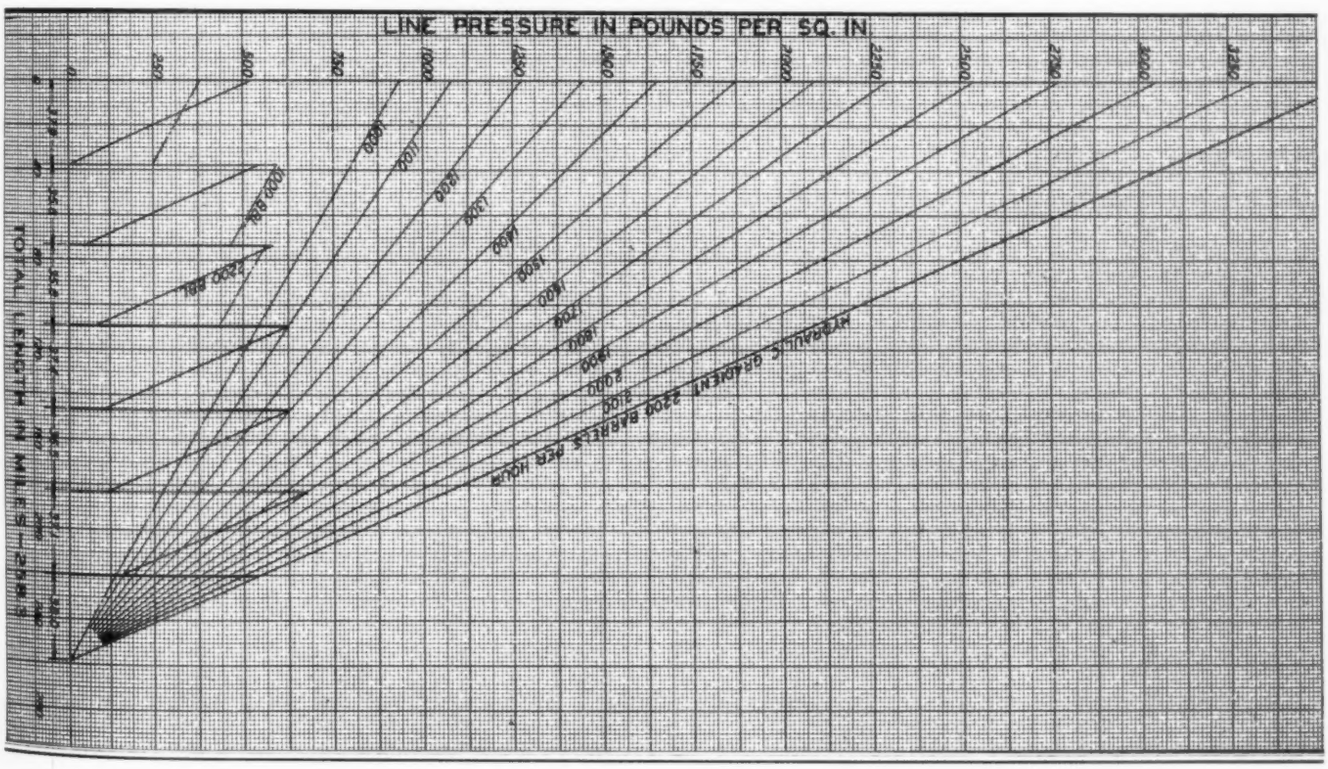
The entire system of 258.3 miles would be controlled from station number one, the initial point, and each of the other six stations would be equipped with electrical control devices, making them fully automatic, capable of taking care of every emergency which might arise.

The control room of station number one would contain six master control panels, similar to the one illustrated in figure number 1. These panels would be arranged in a semi-circle, one for each of the automatic stations, and in the sequence of the stations, as shown in figure number 2. Thus an operator seated at his desk, in the center of the semi-circle, by glancing at the panels keeps informed as to the operating conditions at each station.

These master control panels contain a picture of the equipment at each station, arranged in proper relation to each other, with signal lights indicating the operating conditions, and switches for the control of the valves and the motor-pump units.

Referring to figure 1, the colored signal lights above each of the motor-operated valves and pump units indicate whether the valve is open or closed and the pump running or stopped. By means of the switches, located above the motors 1, 2 and 3, the operator at the master control point is enabled to open or close the valves and start or stop the corresponding pumping units. Emergency conditions, such as hot bearings on either motor or pump, broken pipe lines, etc., are indicated by red signal lights and an alarm sounded to attract the attention of the operator. When emergency conditions arise, the operator dispatches a maintenance crew to the station to correct the trouble. Protective equipment provided for each fully automatic station includes:

1. Thermal controls installed in the bearings of the pumps and motors. These controls are connected with the auto-



matic panels and, in case of excess temperature, stop the units and signal to the master control point.

2. Pressure control, connected in the suction line. This control is connected with the automatic panel to prevent starting of pump motors until the suction pressure has reached a predetermined value, and to stop the unit in case of loss of suction pressure.

3. Sump pump controls. The sump pump is automatically started when the fluid reaches a high level in the sump and is stopped when the low level is reached. In case of excessively high level in the sump, indicating excess leakage at the main pumps, the station is shut down and a signal sent to the master control point, reporting the trouble.

4. Pressure control on the discharge side of the station. In case of a broken line the pressure will drop very quickly and the control is so connected with the automatic system that the units are stopped, the valves are closed and a signal is sent to the master control point, reporting the trouble.

5. A system of relays is installed in the automatic control panel which interconnects the various equipments and insures their operating in the proper sequence. These relays are also interconnected with the master control system to send the signals to the control point, indicating the operating conditions.

6. Signals between the master control point and all the automatic stations are transmitted on a total of two telephone wires. The system is so designed that signals may be sent in both directions at the same time, but signals in the same direction cannot become confused, and, if more than one is to be sent, each must wait until the other signal has been completed and will then be sent.

The pipe line system described in the first section of this article is an ideal application for this automatic control. Flexibility of pipe line pumping capacity is secured through the selection of the proper centrifugal pumps at each of the seven stations, and this could be entirely under the control of one operator at the master control point. The previous article detailed in tabulated form the various combinations of pumps necessary to deliver different capacities. With this table the operator or dispatcher at the control point could start or stop the pumps in each station, corresponding with the volume of oil to be pumped. Thus, assuming the pipe line to be pumping 1,500 barrels an hour, the units in the station would be operated as follows:

Station No. 1	Pump "B"
Station No. 2	Pumps "B" and "C"
Station No. 3	Pump "C"
Station No. 4	Pump "B"
Station No. 5	Pump "B"
Station No. 6	Pump "B"
Station No. 7	Pump "C"

If this volume is to be increased to 2,000 barrels per hour, the operator at the master control point would set up on each control panel corresponding to the automatic stations, in consecutive order, signals which would open or close valves and start or stop pumps, which would give the following results:

Station No. 1	Pumps "A" and "B"
Station No. 2	Pumps "A" and "C"
Station No. 3	Pump "A"
Station No. 4	Pumps "A" and "B"
Station No. 5	Pump "A"
Station No. 6	Pumps "A" and "C"
Station No. 7	Pumps "A" and "C"

When the signals set up by the operator have been dispatched to each of the automatic stations and the operations are completed, signal lights on the master control panels change and these inform the attendant that the proper pump units are in operation.

Investigation has determined that these changes in the starting and stopping of the pumps in all of the automatic stations may be made as rapidly as the dispatcher can set up his signals, starting with number two station (the pumps in number one station having been previously changed) and taking each station in consecutive order. In other words, the pipe line is a "closed" system and changes in pressure from one end to the other take place instantaneously. Thus, when increasing the flow of fluid from the initial point it is not necessary for the dispatcher to start additional pumps at station number one and wait for the suction pressure to build up at station number two, since the increased pressure is delivered to station number two as quickly as the additional pumps are started at station number one. This operating principal applies to the entire pipe line.

The combination of the variable pressure centrifugal pumps for a pipe line as outlined, with the fully automatic pumping stations and master control system, produces results which have been the objective of pipe line executives and engineers and which may be summarized as follows:

(1) Low initial investment in station equipment.

(2) Extreme flexibility in volumes of fluid pumped.

(3) Complete control of entire system from one central point, with definite information as to all operating conditions.

(4) Low operating cost per barrel of fluid delivered.

(5) Reliability of operation and dependability of control and equipment.

(6) Centralized responsibility of all operations.

(7) Elimination of expensive stations, cottages, etc.—no attendants required, since stations are fully automatic.

(8) Minimum repair, maintenance and supervision costs.

(9) In the event of moving a system, minimum costs in moving station installations, since equipments are small, light and controls fully portable.

Thus, with the numerous desirable features as outlined above, it is safe to predict that many pipe line systems of the future will contain pumps arranged as described and that they will be automatic and controlled from a central point.